

Final Report

Impact of Rainstorms on Marine Recreational Water Quality of Beaches Adjacent to Lagoons in San Diego California

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Prepared by
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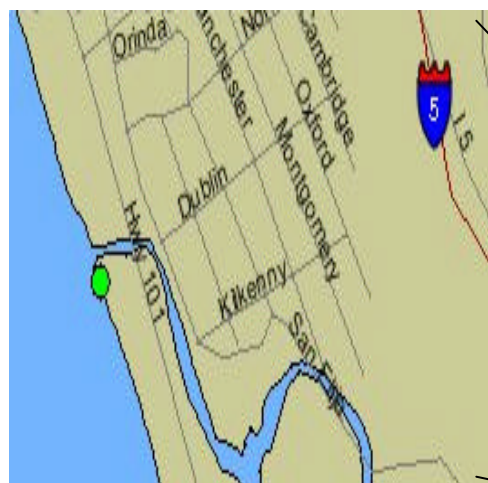
1 Introduction

Fecal indicator bacteria in coastal waters are largely derived from: (1) urban runoff from irrigation systems and street wash-down activities, (2) discharges of treated or untreated sewage either directly to the ocean or via rivers and streams; (3) storm water runoff from adjacent land areas; and (4) waste inputs from birds, especially in the intertidal zone. Bacterial beach water quality varies with the magnitude of the above-mentioned inputs, the flux and dispersion of microorganisms as a result of near-shore hydrodynamics, the rate of die-off as a consequence of exposure to sunlight, and the rates of deposition and entrainment. Recent studies have shown that streams and rivers can account for a high proportion of pathogens and fecal indicator bacteria entering the coastal zone. The concentrations of indicator bacteria exhibit significant positive correlations with land use and management variables (Crowther et al., 2002). Enterococci bacteria generated in a tidal saltwater marsh located near the beach significantly impact surf zone water quality (Grant et al., 2001).

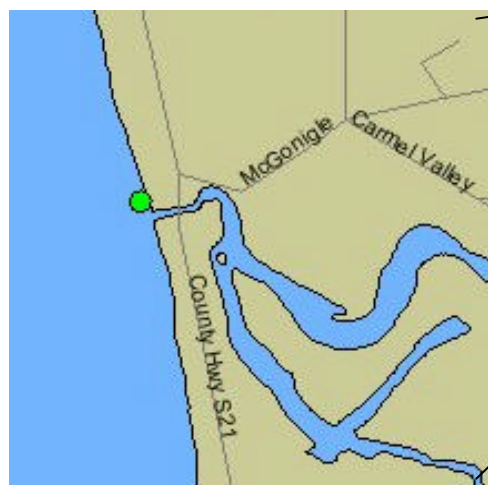
Currently, it is unknown how and to what degree lagoon systems impact the recreational use of adjacent ocean shoreline beach water quality. There are six lagoon systems that directly discharge to marine coastal beaches in San Diego County. These systems drain large areas of agricultural, residential, commercial, and/or municipal lands that are potential bacterial sources. The current practice of informing the public of the likelihood for contamination of beach water is to issue a general advisory for 72 hours after 0.2 or more inches of rain. To better manage recreational water use, there is a need to better understand the rainfall-lagoon-beach interaction and its impact on ocean shoreline recreational water quality. The objective of this project was to collect information to better define the temporal and spatial impacts of rain events on ocean shoreline beaches adjacent to lagoon systems in San Diego California.

2 Study Sites

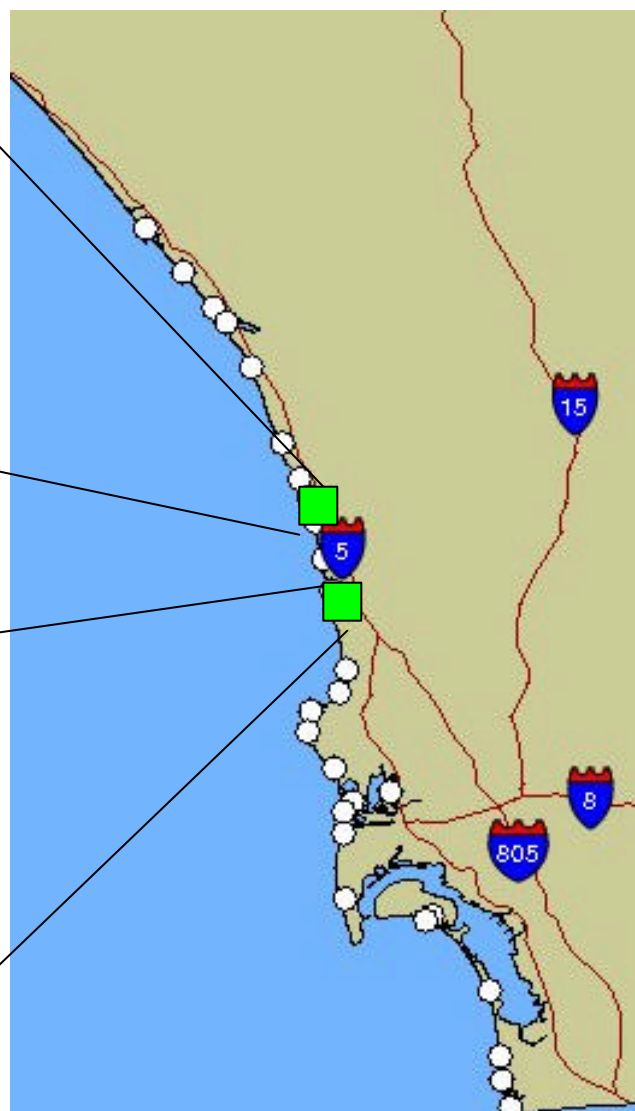
There are six lagoons adjacent to recreational beaches on the ocean shoreline of San Diego County. Two were selected as study sites for this project. They are Torrey Pines State Beach that receives discharge water from Los Penasquitos Lagoon, and Cardiff/San Elijo State Beaches that receive discharge water from San Elijo Lagoon (Figure 1). Los Penasquitos Lagoon (Figure 2) is located at the northwestern border of the City of San Diego, directly south of the City of Del Mar. San Elijo Lagoon (Figure 3) is located 20 miles north of San Diego, between the cities of Solana Beach and Encinitas.



San Elijo/Cardiff State Beaches

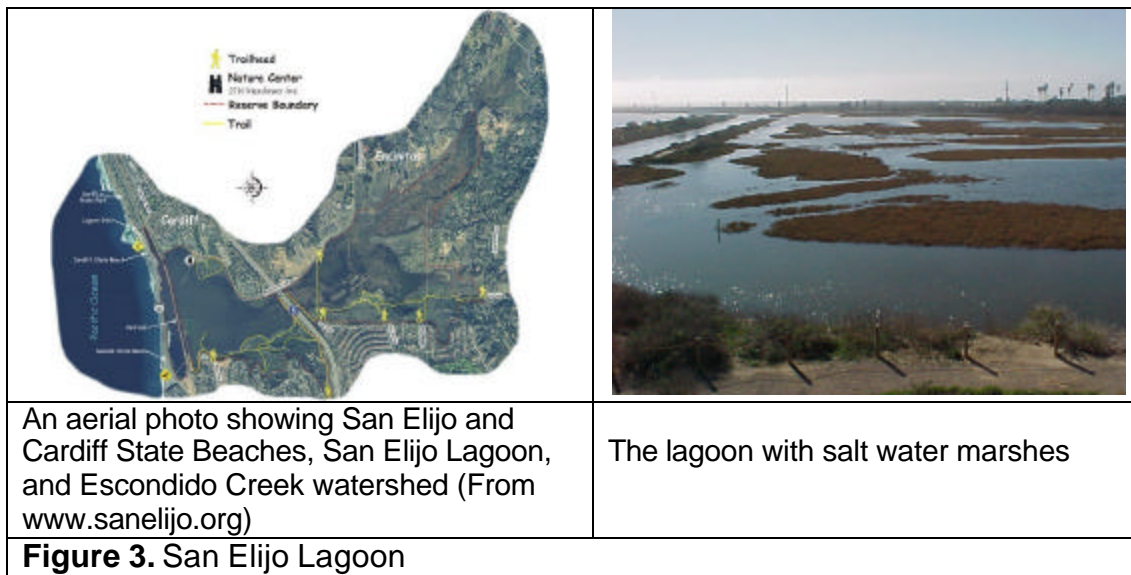
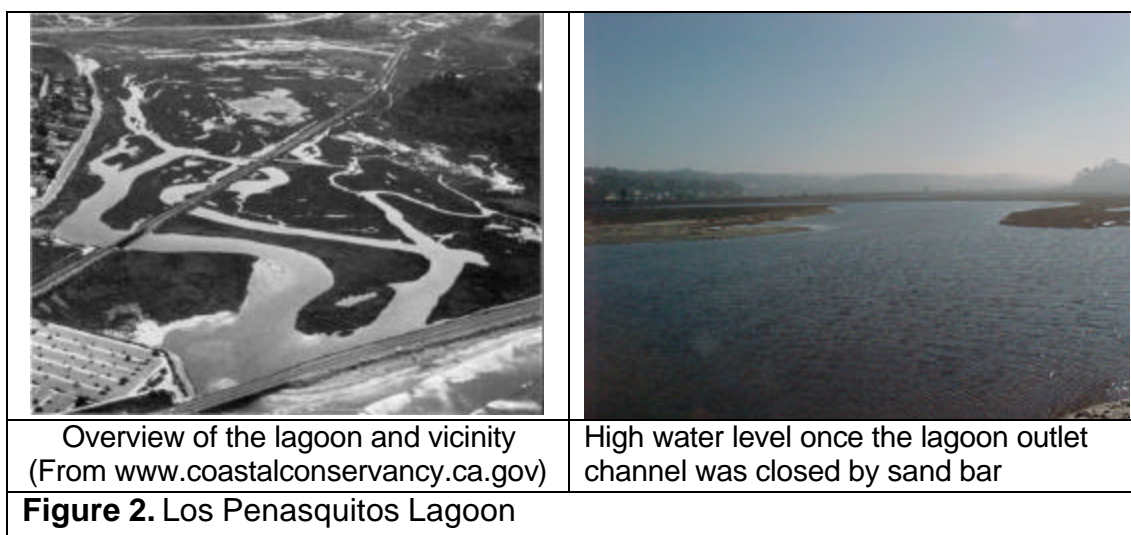


Torrey Pines State Beach



San Diego County Beach Monitoring Stations

Figure 1. Location of two study sites at San Elijo/Cardiff and Torrey Pines State Beaches (From www.earth911.org)



A summary of information on the lagoons is presented in Table 1. These two lagoons were selected because (1) urbanized land-use upstream results in increased stormwater runoff flows to the lagoons and (2) year-round recreational uses occur on the ocean beaches adjacent to the lagoon outlet.

Table 1. Summary of Information on Lagoons and Adjacent Ocean Beaches

State Beach	# Beach Visitors (1989)	Lagoon	Lagoon Area (acre)	Watershed	Watershed Area (acre)
Torrey Pines	1,024,000	Los Penasquitos	425	Penasquitos	60,430
Cardiff and San Elijo	1,809,000	San Elijo	415	Escondido Creek	54,100

3 Field and Laboratory Methods

3.1 Water Sampling

All water samples were taken at eight locations along the shoreline at each lagoon (Figure 4).

- At the lagoon outlet channel.
- At the lagoon water and ocean water mixing zone.
- At 25, 50, 100 yards southward from the mixing zone.
- At 25, 50, 100 yards northward from the mixing zone.

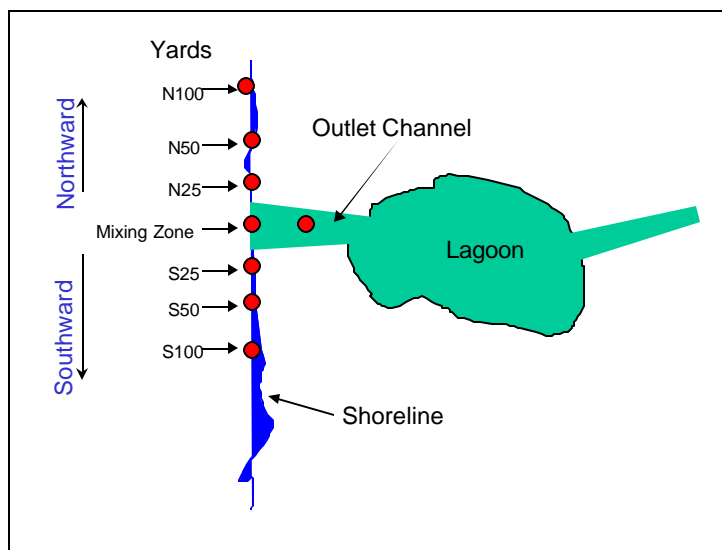


Figure 4. Schematic diagram for sampling locations (red dots)

Water samples were taken 4-6 inches below the water surface in knee-deep water (~20 inches) at all locations. All beach water samples were collected on an incoming wave in 125-ml sterile plastic bottles, placed on ice, and delivered to the laboratory so that analysis may begin within 6 hours. Lagoon outlet channel samples were collected as close to the center of the channel as can be safely accessed.

A sampling pole was used to collect water samples. An uncapped bottle was submerged under water, rotated to side (90 degrees), and swept horizontally keeping the bottle at even level under the water surface. Samples were delivered to a public health laboratory for measuring total coliform, fecal coliform, and enterococcus.

This study was designed to assess the bacterial water quality of recreational ocean shoreline beaches with an emphasis on potential impacts of rainstorms through lagoons. During the wet season water samples were collected at all pre-selected locations as shown in Figure 4 following a = 0.2-inch storm event during ebb tides. Following the first sampling, samples were collected in the same tide window as the first sample every 24 hours up to 96 hours (4 days). The same sampling pattern was followed throughout the study, and samples at a specific location were taken at the same time window to minimize the effect of sunlight and salinity on the die-off of bacteria.

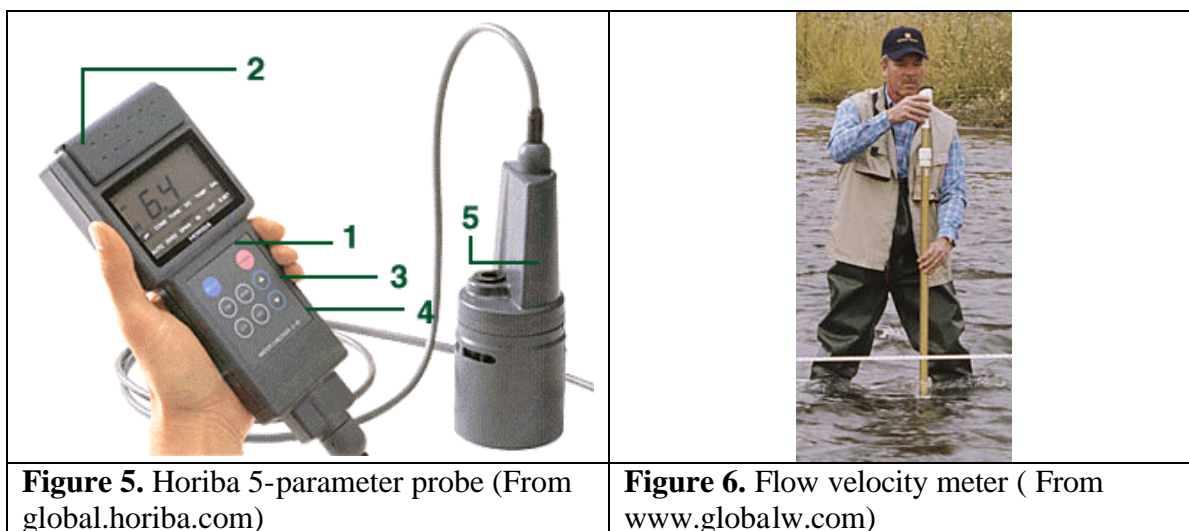
Two rainstorm events that met the minimum requirements were conducted for this study. The first rainstorm event, which was on March 15, 2003, had about 2 inches of rainfall, and the second event on April 14, 2003 had 1.8 inches of rainfall.

During dry weather events, ambient monitoring was conducted at the pre-selected locations as for wet weather seasons at a typical ebb low tide when the lagoon outlet channel was open. Results from ambient monitoring were used to assess the degree of the impact of rainstorm on recreational water quality. Two sampling events were planned for dry weather days in this study, but only one event was performed as of date and the data for the event is presented herein.

3.2 Field Measurement

Physicochemical properties of water were determined using a portable multiprobe system (Horiba U-10) (Figure 5). Water parameters included pH, temperature, conductivity, turbidity, and dissolved oxygen. Salinity was calculated from conductivity.

The lagoon outlet flow rate in cubic feet per second (CFS) was obtained by measuring the water depth, channel width, and flow velocity. The flow velocity was measured using a flow probe (FP101 Global Flow Probe, Gold River, CA) (Figure 6).



Rainfall data were collected at the following stations for San Elijo Lagoon: Encinitas, Solana Beach, Escondido, Harmony Grove, Lake Wohlford, and Olivenhain; and for Los Penasquitos Lagoon: Del Mar, Miramar MCAS, Kearny Mesa, Miramar Lake, Poway, and Mt. Woodson. Rainfall data were averaged from the stations for each lagoon.

During water sampling, the number of birds, visible bird waste, and the number of swimmers and surfers, if any, were recorded at the sample site in the field. Tide height was calculated using the time when the sample was collected. The direction of littoral current was estimated using the “orange method” (Grant *et al.*, 2003) by observing the direction of floating orange movement.

3.3 Laboratory Analysis

All water samples were analyzed for total and fecal coliforms and enterococci using methods recommended by the California Department of Health Services. The multiple tube fermentation (MTF) method (Standard Method 9221 B and E) was used for measuring total and fecal coliforms. Results were expressed as most probable number (MPN) per 100 mL of water. Water samples were analyzed with the 15-tube MTF method that produces a maximum number of 16, 000 MPN/100 mL. Feces-contaminated water samples, for example, at lagoon outlet channel or after rainstorm, were analyzed with the 25-tube MTF method, which generates a maximum number of 1,600, 000 MPN/100 mL.

The IDEXX Enterolert method (Standard Method 9223 B Enzyme Substrate Test) was used for measuring enterococcus bacteria. Results were expressed as most probable number (MPN) per 100 mL of water. Enterolert uses a Defined Substrate Technology[®] (DST[®]) nutrient-indicator to detect enterococci. This nutrient-indicator fluoresces when metabolized by enterococci. The 96-well Quanti-Tray was used for all samples or otherwise indicated, which allows for an MPN counting between 10 and 24,192 MPN/100 mL.

3.4 Public Notification of Beach Water Quality

For each bacterial exceedence determined in this project, the public was notified by posting advisory signs at the beach, inclusion on the Beach and Bay Status Report phone recording (619.338.2073), and listing on the Earth 911 web page (www.california.earth911.org).

4 Results and discussion

4.1 Physicochemical Results

Six physicochemical parameters were obtained for this study: Temperature, pH, conductivity, dissolved oxygen, turbidity, and salinity. All data of physicochemical properties are presented in Tables 2 and 3. Since temperature, pH, and dissolved oxygen showed less variability spatially and temporally, and conductivity is related to salinity, only two parameters – salinity and turbidity are discussed below.

4.1.1 Salinity

The lagoon outlet channel showed the lowest salinity and the mixing zone the second lowest (Figures 7 and 8). After a rainstorm, the salinity decreased dramatically (Figures 7A, B, and D). At San Elijo State Beach, the salinity was lower during dry days (March 13 and 14) than rain days (March 16 and 17). This is due to change in sampling time. On March 13 and 14, water sampling and field measurements were performed first at Torrey Pines in the morning and then San Elijo in the afternoon. There were low tides in the afternoon and more fresh water was pulled out from the lagoon to the beach through the outlet channel. It was intended to avoid high tides while sampling in the morning, and sampling was performed first at San Elijo and then at Torrey Pines after March 14.

The salinity on both south and north sides from the channel was similar. However, wind and current direction exhibited a significant effect on the salinity distribution at the beach adjacent to a lagoon. For example, on March 17 and April 15, salinity was higher on north side than south side (Figures 7A, B, and D) because the littoral current moved from north to south. On the contrary, on April 17, the southerly current resulted in a lower salinity on north side (Figures 7B and D).

4.1.2 Turbidity

Turbidity is caused by particulates suspended in water. These suspended particulates can originate from storm runoff or marine sediment resuspension by near shore tides. It is evident that rainstorm resulted in higher turbidity in all locations at Torrey Pines State Beach and San Elijo State Beach (Figures 8A-D), although the distribution pattern has fluctuations at San Elijo State Beach. The turbidity data at San Elijo was likely impacted by high tides in the morning, which would resuspend on-shore fine sediments into water column.

4.2 Microbiological Results

Three indicator bacteria (total coliform, fecal coliform, and enterococcus) were measured at each sampling location. The concentration of these indicators was high at the lagoon outlet channel and the mixing zone before and after rainstorms (Figures 9-12). After a rainstorm, urban runoff, which carries high levels of bacteria, flushes to the beach through the lagoon outlet. The large amount of runoff water can be readily transported along the shoreline by strong rip currents and by northerly or southerly waves, resulting in high bacterial concentration even beyond 100 yards from the channel after a rainstorm (Figures 9-12). By comparing the recreational water quality standard established by the California Department of Health Services: 10,000 MPN/100 mL for total coliform, 400 for fecal coliform, and 104 for enterococcus, the highest number of bacterial exceedence in beach water quality is enterococcus, followed by fecal coliform. These standards are shown as red lines in the data graphs.

The bacterial concentration decreased as runoff flow decreased with time after a rainstorm and bacteria were likely to die off in seawater. All three bacterial indicators were below the marine recreational water quality criteria three days, i.e., 72 hours, after a rainstorm (Figures 9-12).

The pattern of bacterial distribution at Torrey Pines State Beach differs from that at San Elijo State Beach. At Torrey Pines State Beach, bacterial levels were similar on north and south sides (Figures 9-10). At San Elijo State Beach, however, the bacterial concentration was higher on the south side than the north side. This can be explained as follows. Torrey Pines State Beach has relatively straight shoreline, and the water from the lagoon would be evenly distributed to both south and north sides through rip currents. San Elijo State Beach has a trough on the south side and more water from the lagoon would flow to the trough on the south side than the north side, leading to higher bacterial concentrations on the south side.

All data of microbiological results are presented in Tables 2 and 3.

5 Conclusions

The results presented above indicate that rainstorms exert a significant impact on the marine recreational water quality of beaches adjacent to lagoons during the first 24 to 48 hours after a storm. Beach water contains high concentrations of bacteria after a storm not only at the lagoon outlet channel and the mixing zone, but also at locations 100 yards away from the channel along the shoreline. The bacterial concentration decreases to a level below the water quality criteria 72 hours after a storm. Enterococci exhibit more exceedences than total and fecal coliforms. The geology and shape of beach shoreline have an influence on the distribution of bacterial concentration in beach water.

Rainfall events have long been recognized as one of the major impacts on beach water quality. County health departments in southern California typically issue general beach advisories for 72 hours after a rainstorm > 0.2 inch in order to protect the public from unnecessary contact of potentially contaminated beach water. This is the first systematic study that substantiates that the 72 hour general advisory for recreational water contact due to urban runoff contamination following rainfall is adequate to protect public health, even after relatively large rain events (e.g., ~2 inches of rainfall).

While this study focused specifically on marine recreational beaches near large lagoons, conclusions should be applicable to other marine recreational beaches that receive direct discharge from rivers, creeks, and other types of storm conveyances. Since lagoons generally serve as habitat for wildlife such as waterfowl and shorebirds, they are more likely to serve as sources of animal fecal wastes, and therefore of microbiological contaminants to beach water.

6 References

California DHS. 2000. Recommended Methods for the Analysis of Recreational Marine Water to Comply with AB 411. http://www.dhs.ca.gov/ps/ddwem/beaches/ab411_methods.htm. Last Update: March 28, 2000. Accessed August 27, 2002.

Crowther, J., D. Key, and M.D. Wyer. 2002. Faecal-indicator concentrations in waters draining lowland pastoral catchments in the UK: Relationship with land use and farming practices. *Water Research* 36:1725-1734.

Grant, S.B., B.F. Sanders, A.B. Boehm, J.A. Redman, J.H. Kim, R.D. Mršć, A.K. Chu, M. Gouldin, C.D. McGee, N.A. Gardiner, B.H. Jones, J. Svejkský, G. V. Leipzig, and A. Brown. 2001. Generation of Enterococci Bacteria in a Coastal Saltwater Marsh and Its Impact on Surf Zone Water Quality. *Environmental Science & Technology*. 35:2407 – 2416.

Boehm, A. B., S . B . Grant , J . H . Kim , S . L . Mowbray , C . D . McGee , C . D . Clark , |D . M . Foley , and D . E . Wellman. 2002. Decadal and Shorter Period Variability of Surf Zone Water Quality at Huntington Beach, California. *Environmental Science & Technology*. 36:3885-3892.

Boehm, A. B., J.A. Fuhrman, R.D. Mrse, and S.B. Grant. 2003. Tiered Approach for Identification of a Human Fecal Pollution Source at a Recreational Beach: Case Study at Avalon Bay, Catalina Island, California. *Environmental Science & Technology*. 37:

USEPA, 2002a. Implementation Guidance for Ambient Water Quality Criteria for Bacteria. May 2002 Draft. EPA-823-B-02-003

USEPA, 2002b. National Beach Guidance and Performance Criteria for Recreational Waters – Final. EPA-823-B-02-004.

Data Figures

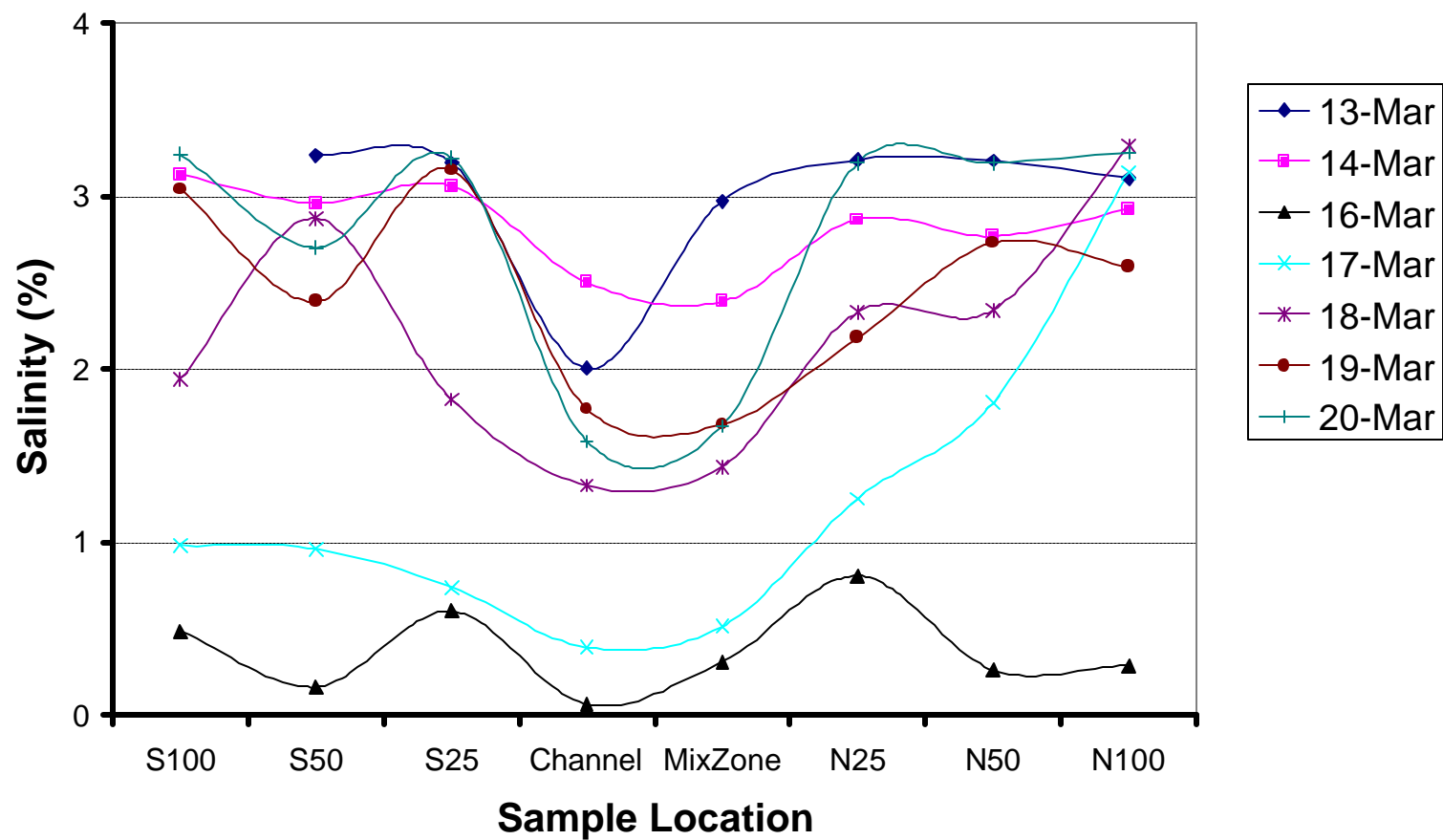


Figure 7A. Salinity at Torrey Pines State Beach

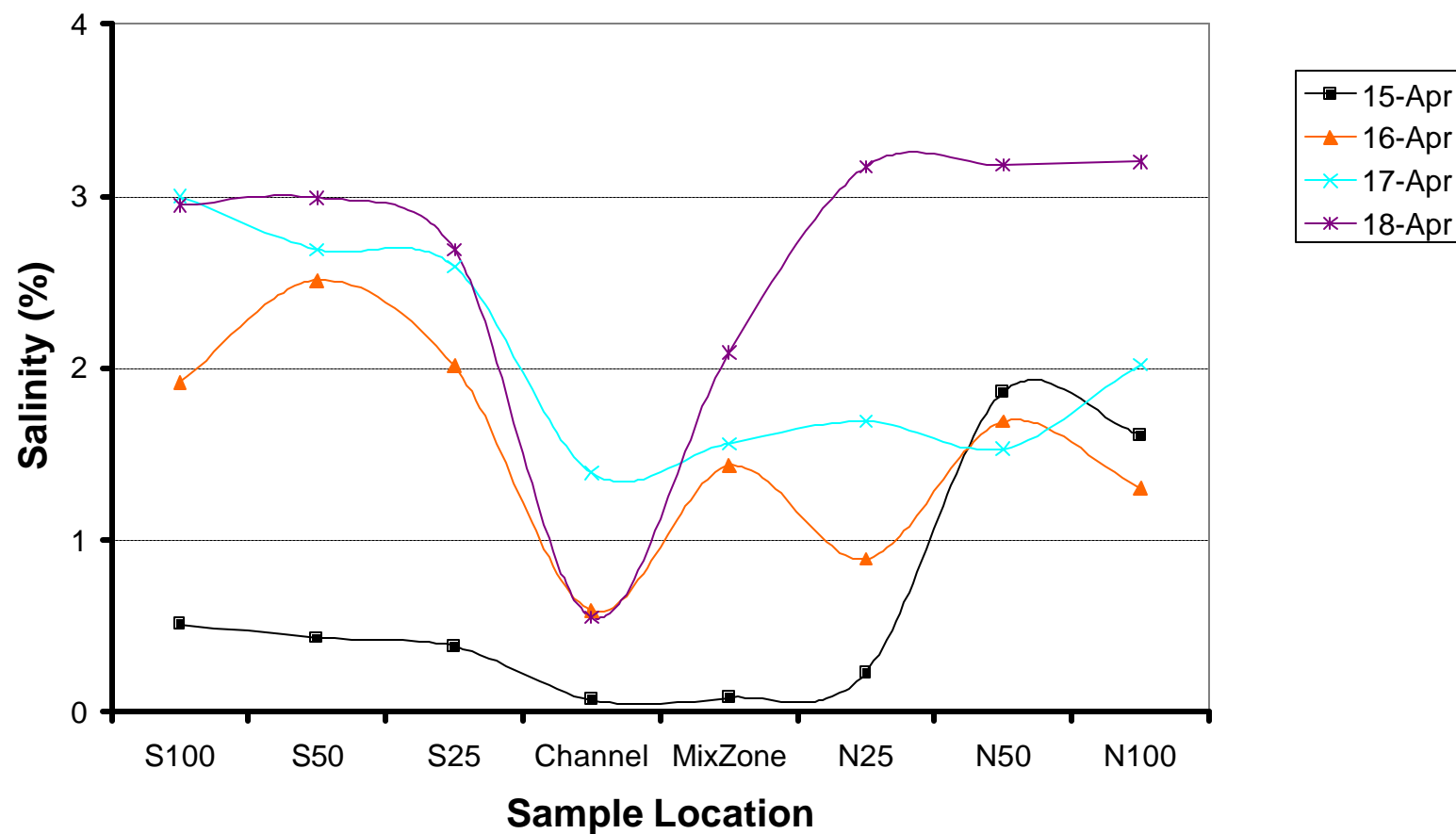


Figure 7B. Salinity at Torrey Pines State Beach

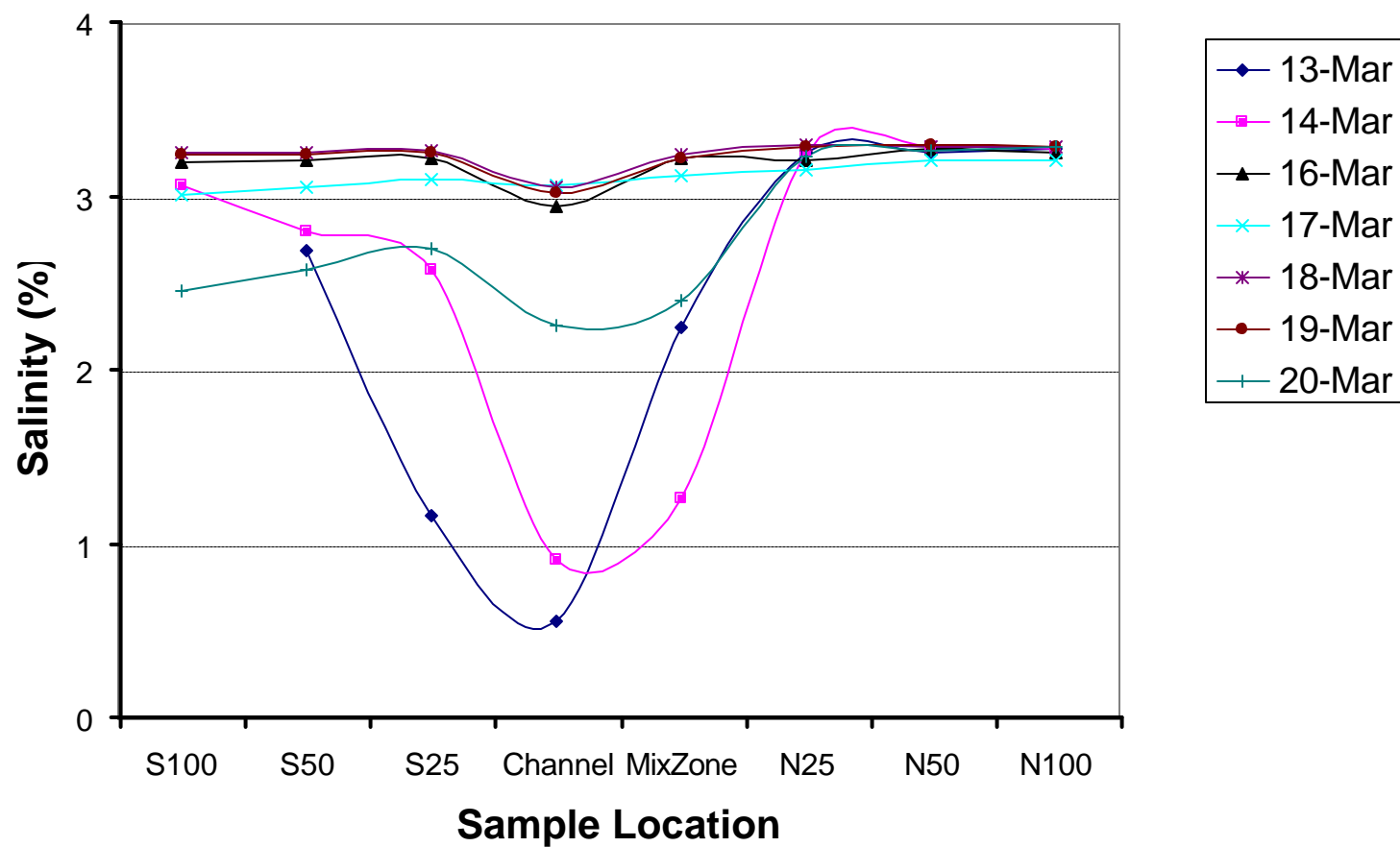
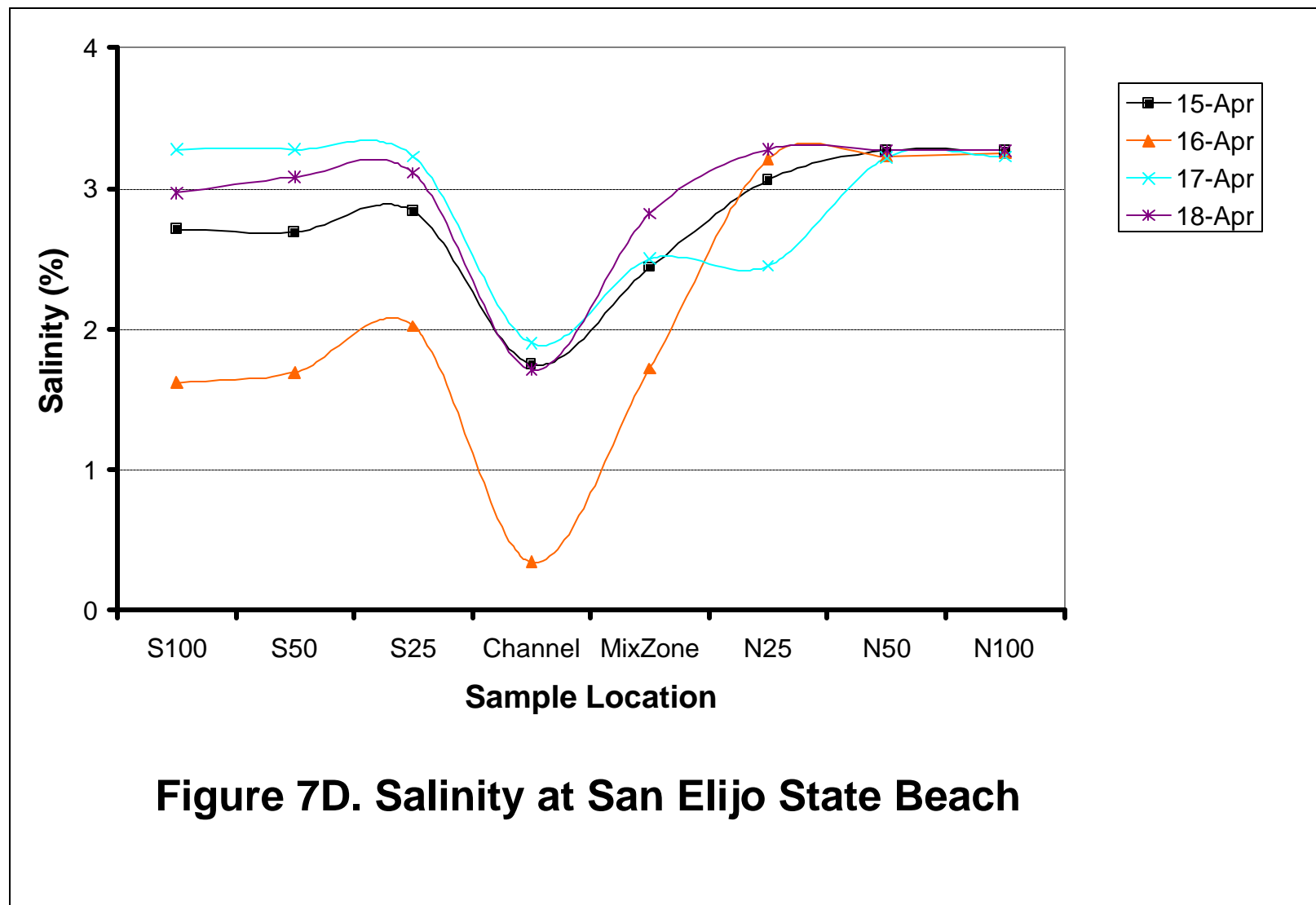


Figure 7C. Salinity at San Elijo State Beach



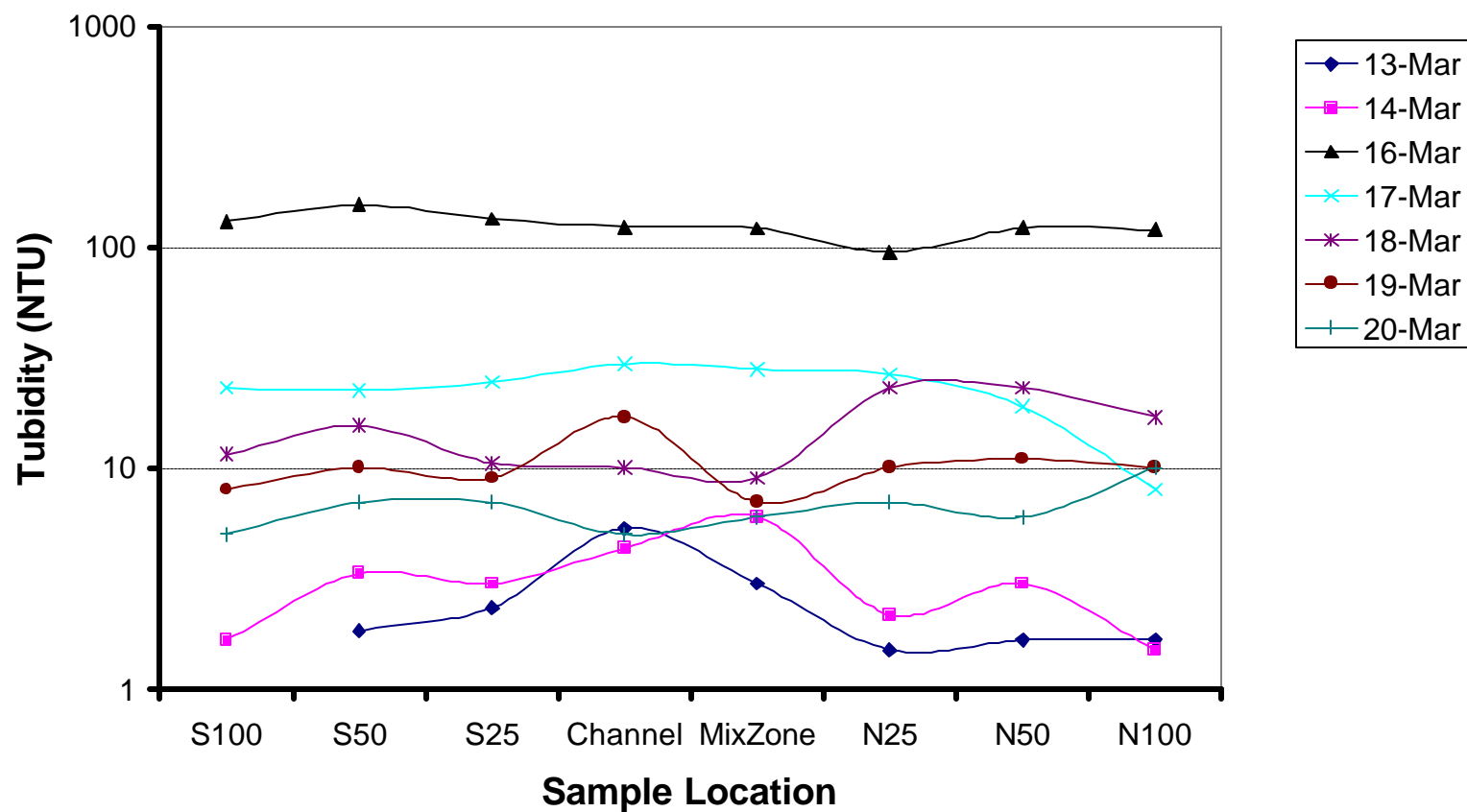


Figure 8A. Turbidity at Torrey Pines State Beach

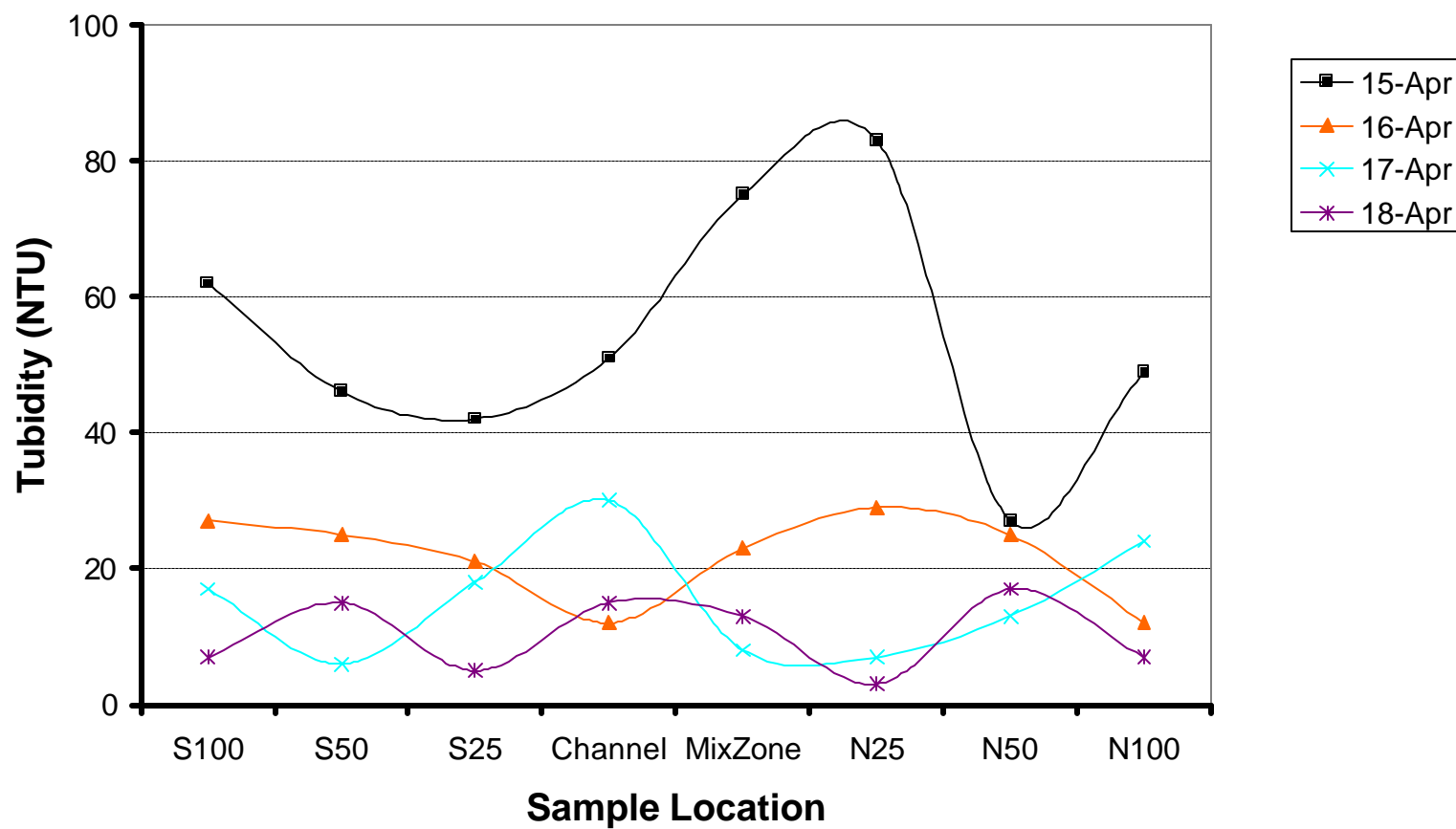


Figure 8B. Turbidity at Torrey Pines State Beach

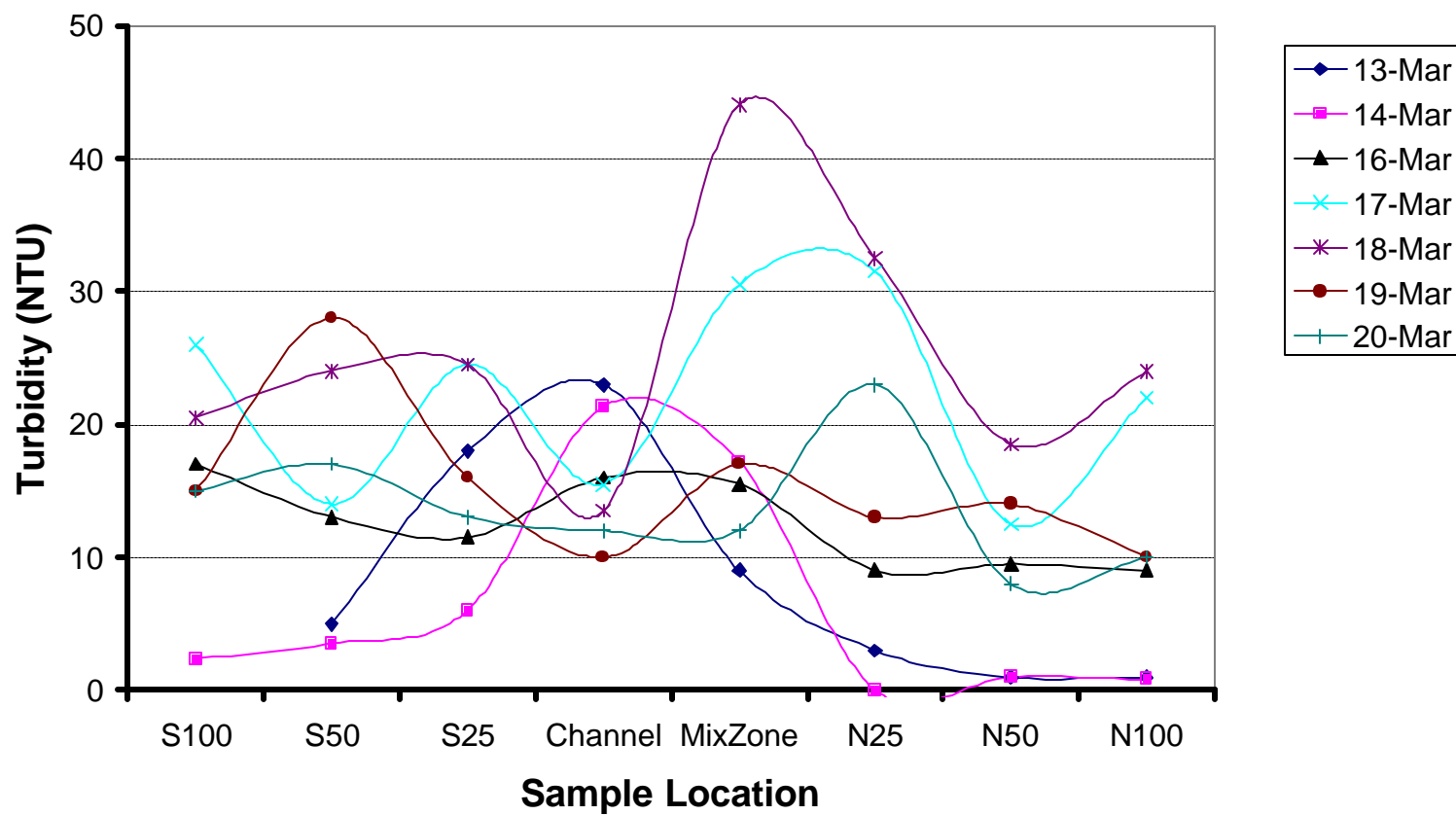


Figure 8C. Turbidity at San Elijo State Beach

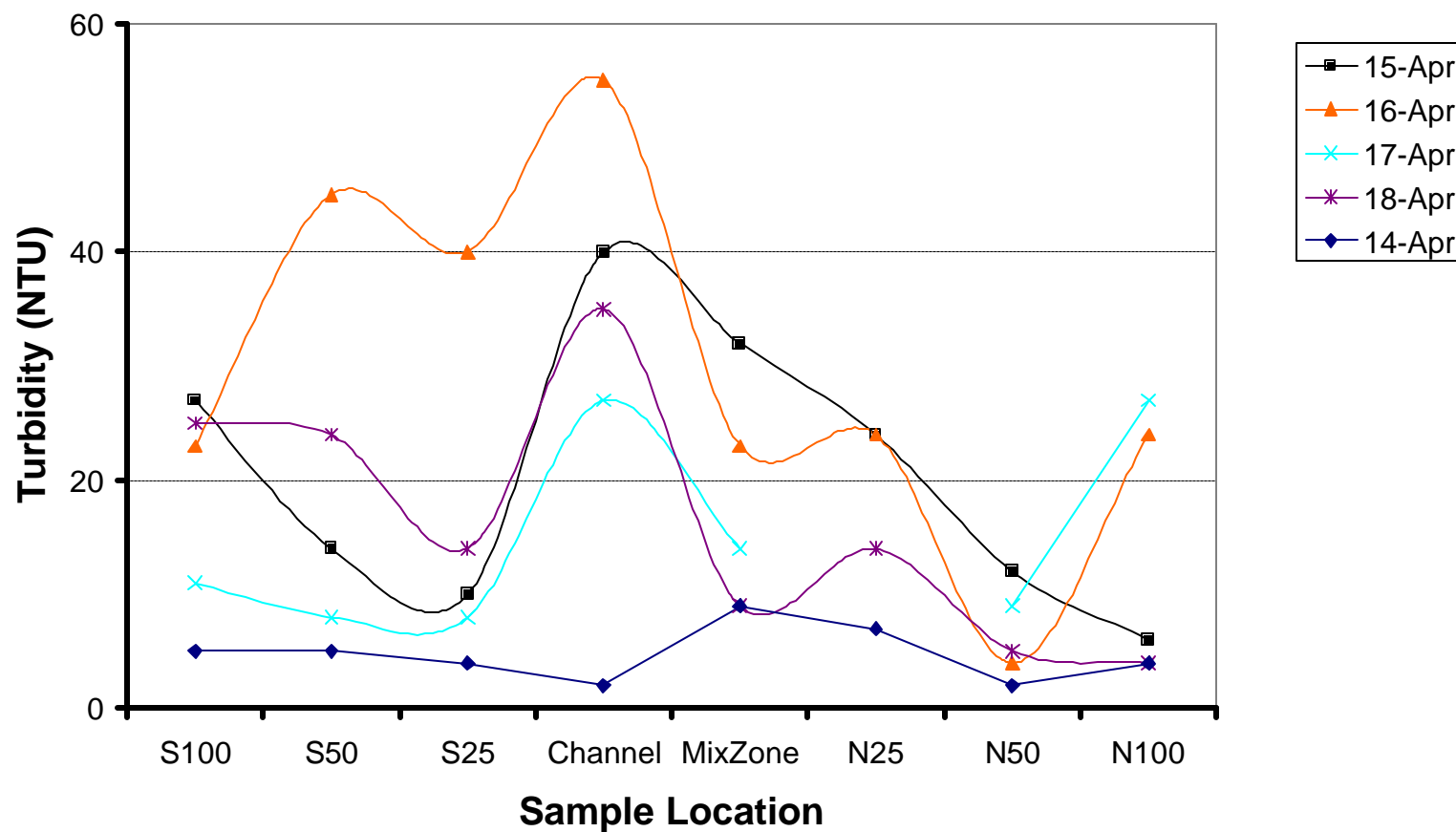
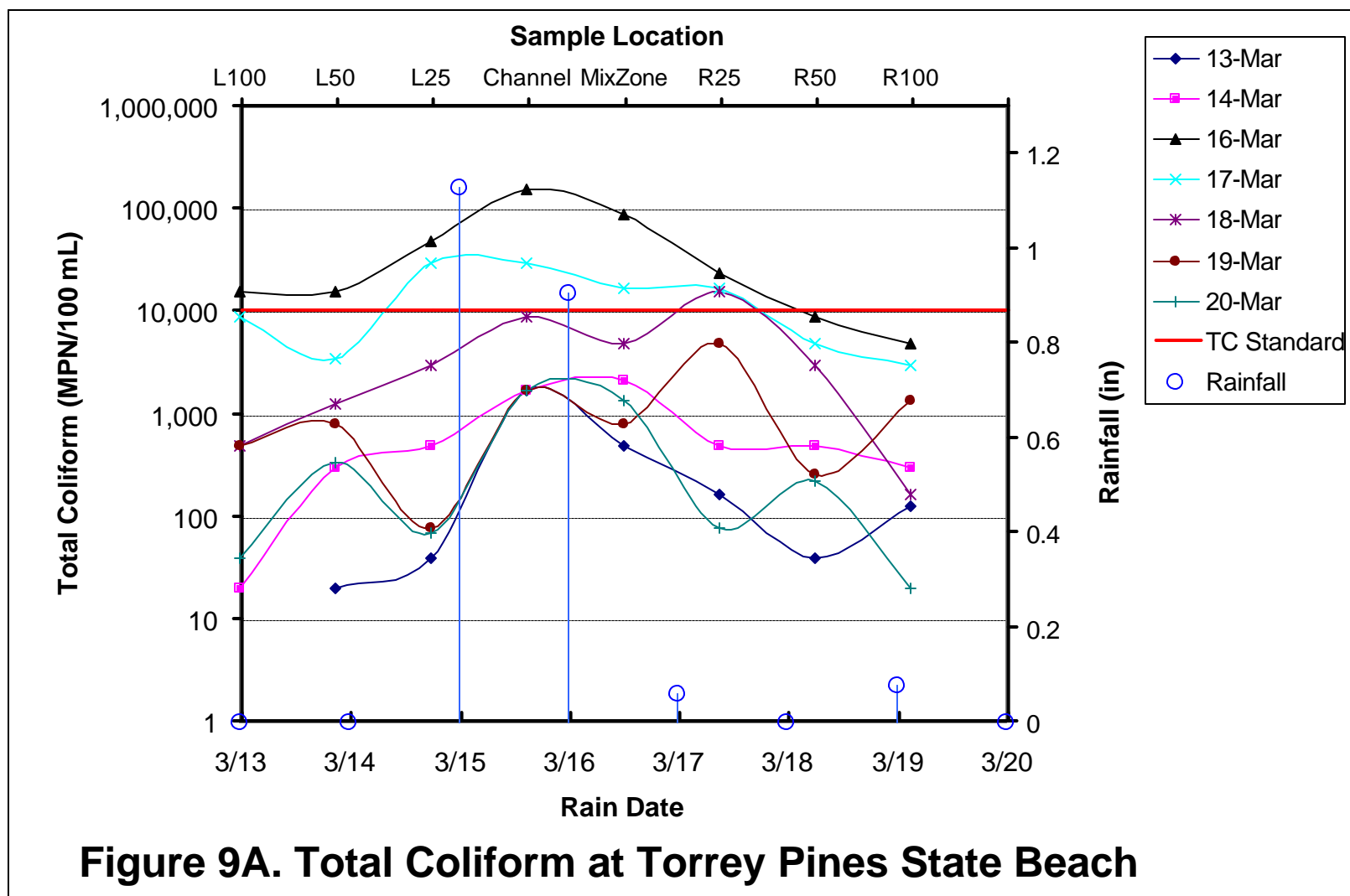


Figure 8D. Turbidity at San Elijo State Beach



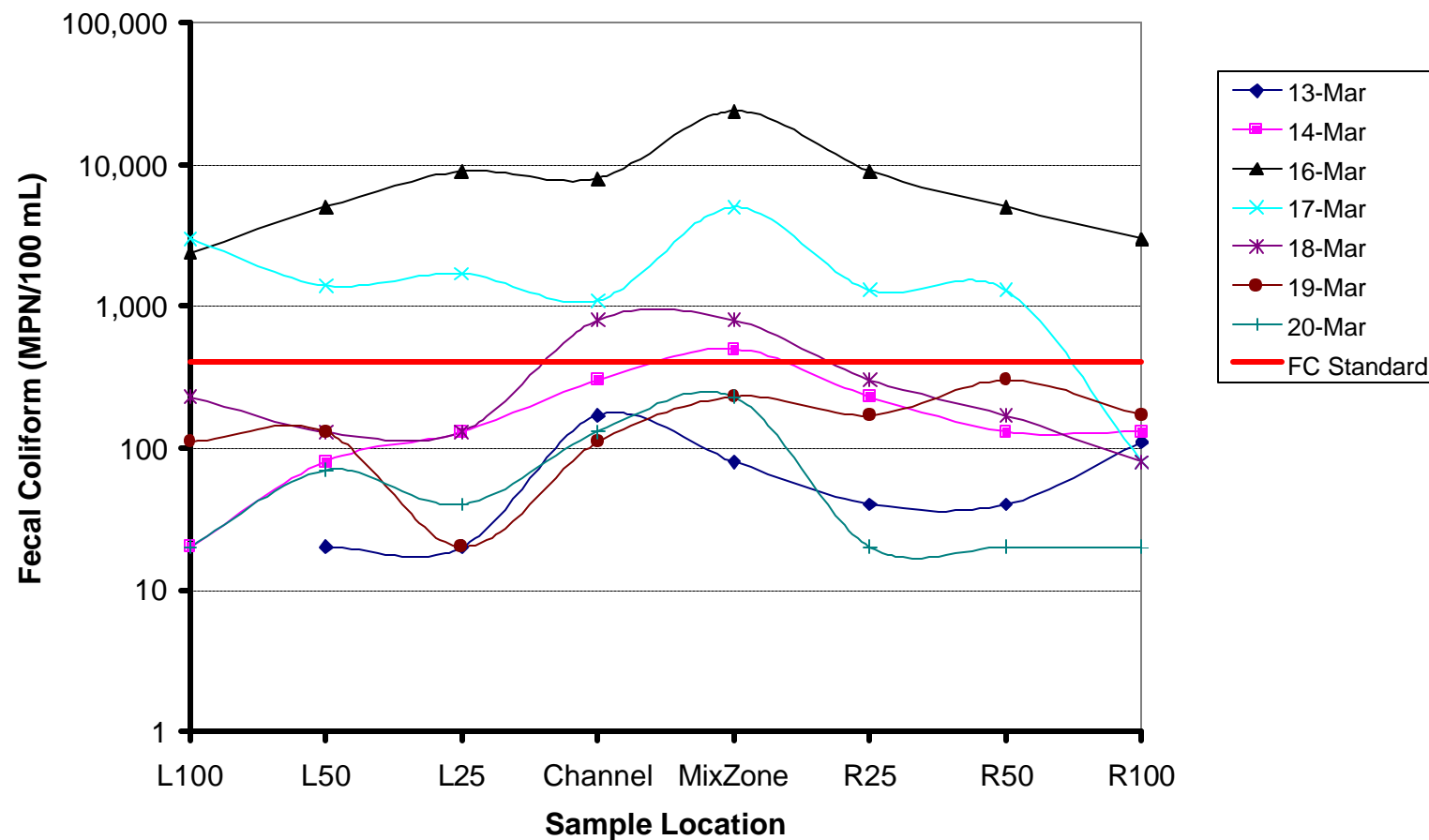


Figure 9B. Fecal Coliform at Torrey Pines State Beach

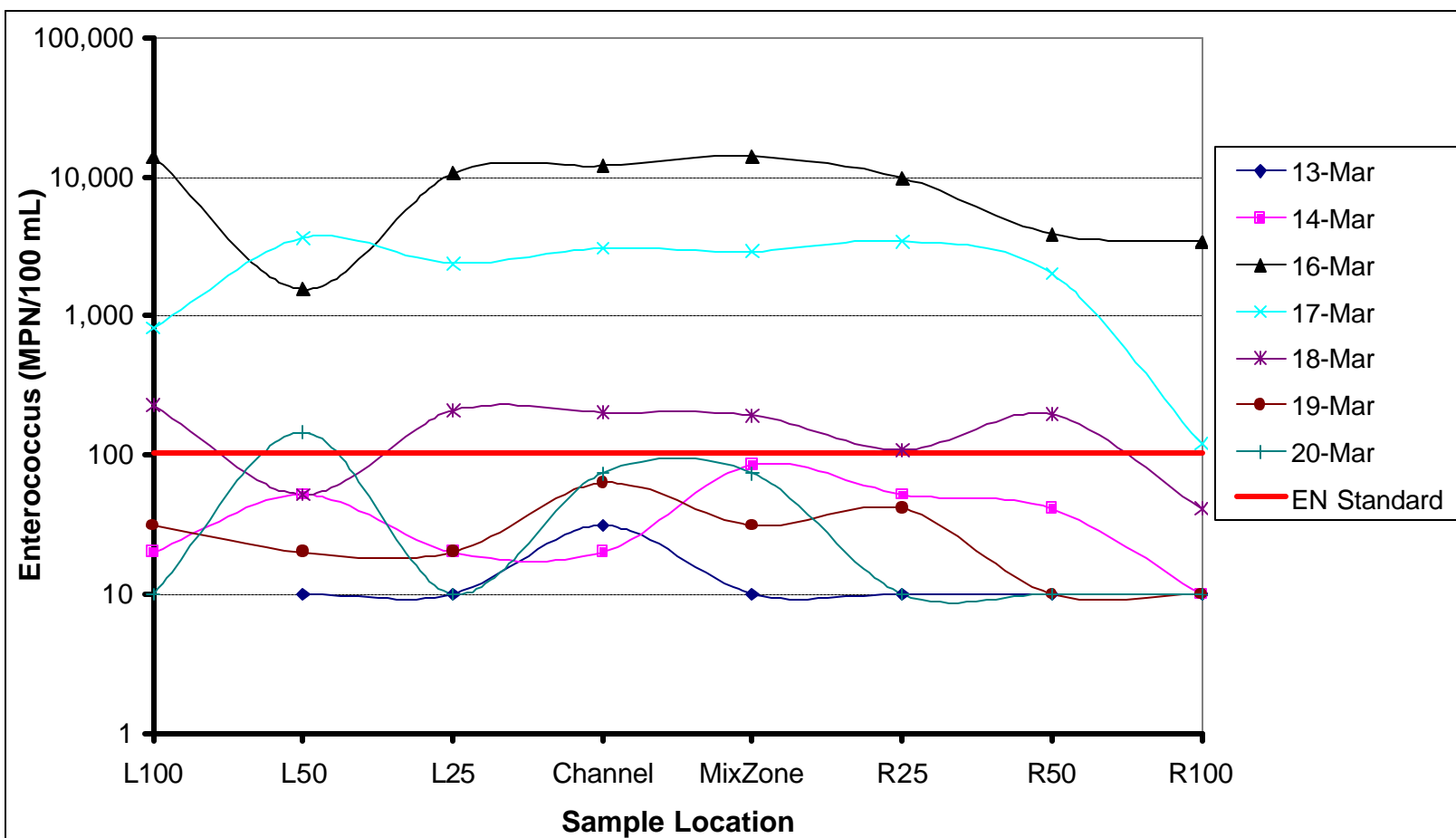
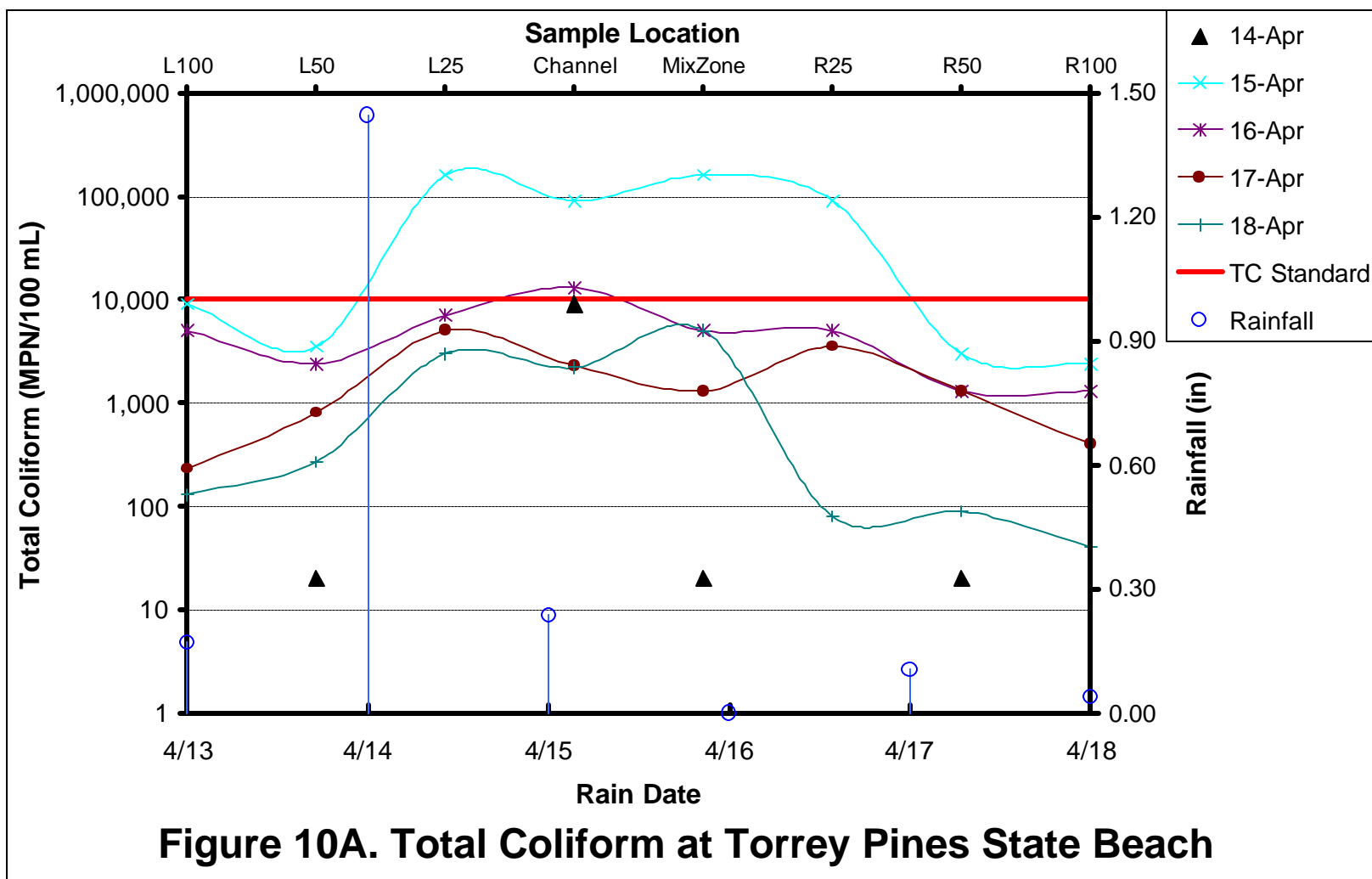
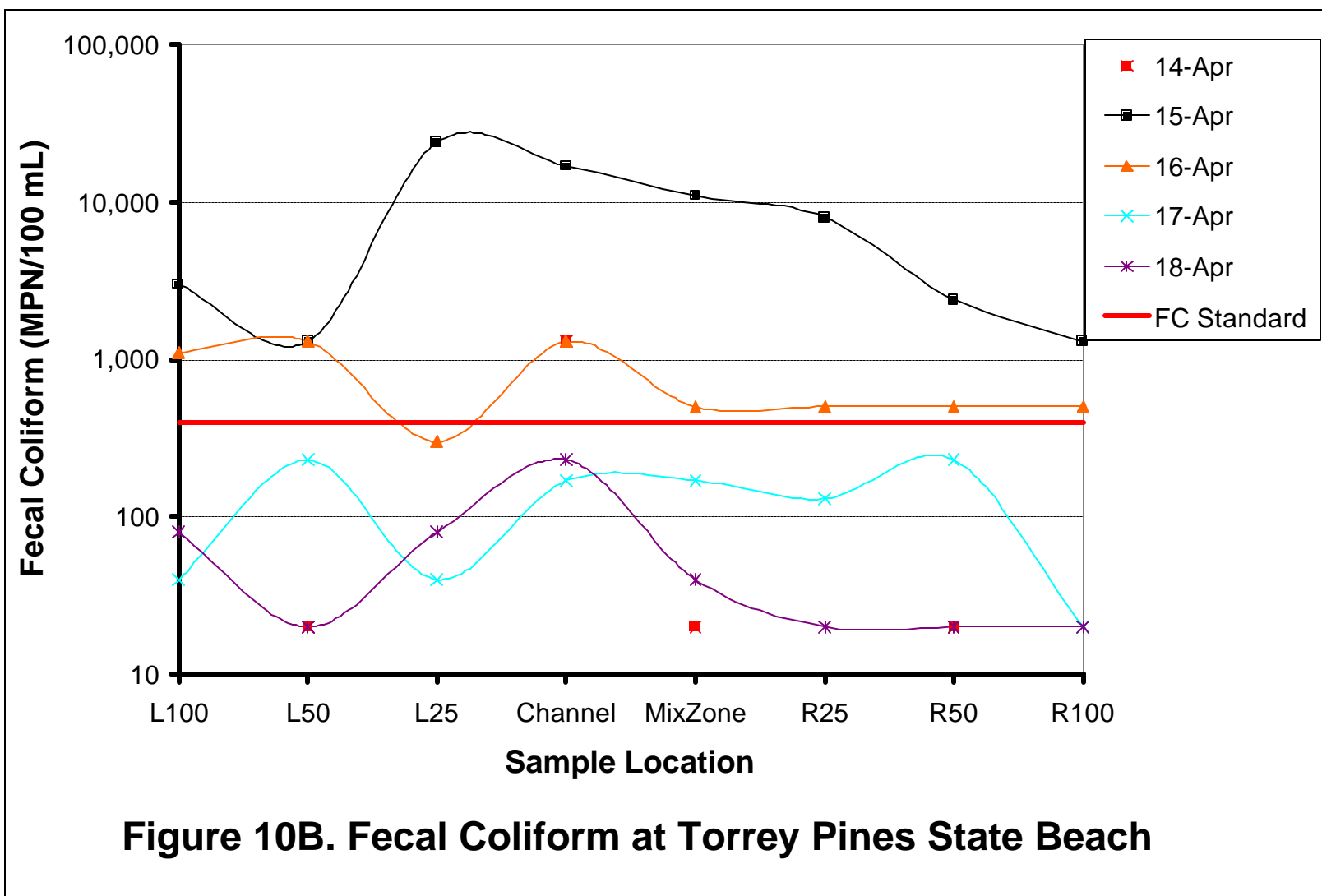
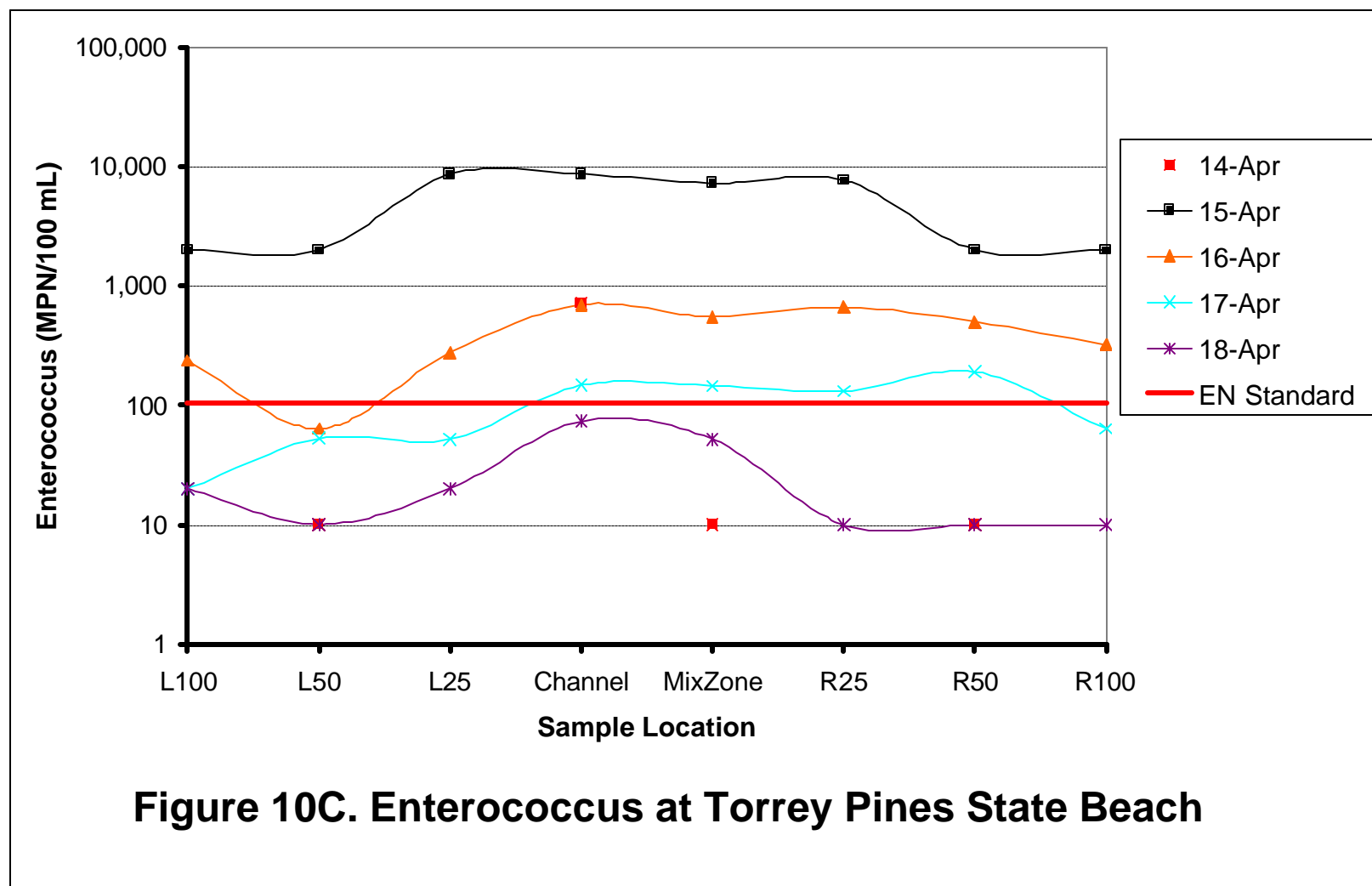


Figure 9C. Enterococcus at Torrey Pines State Beach







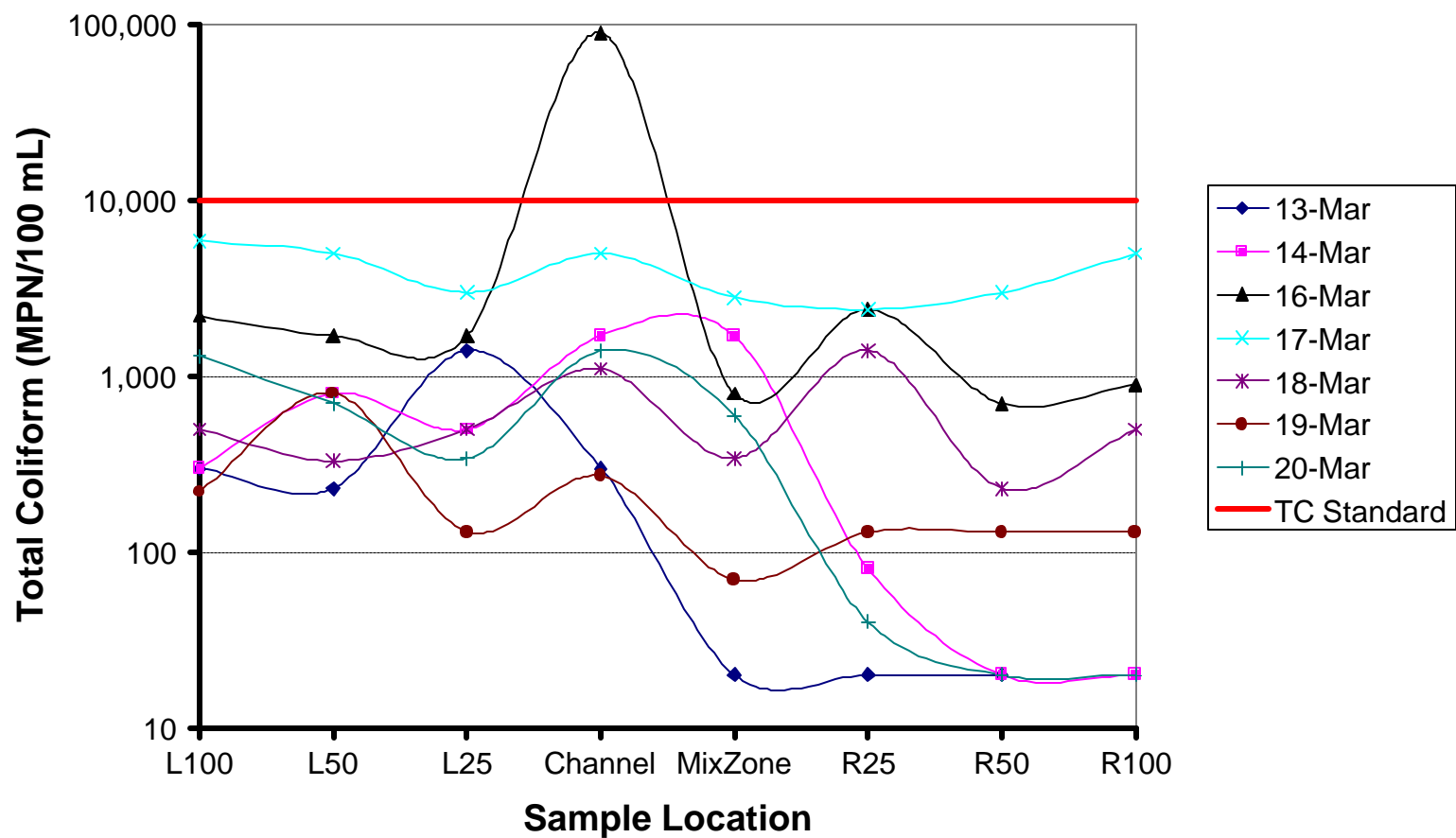


Figure 11A. Total Coliform at San Elijo State Beach

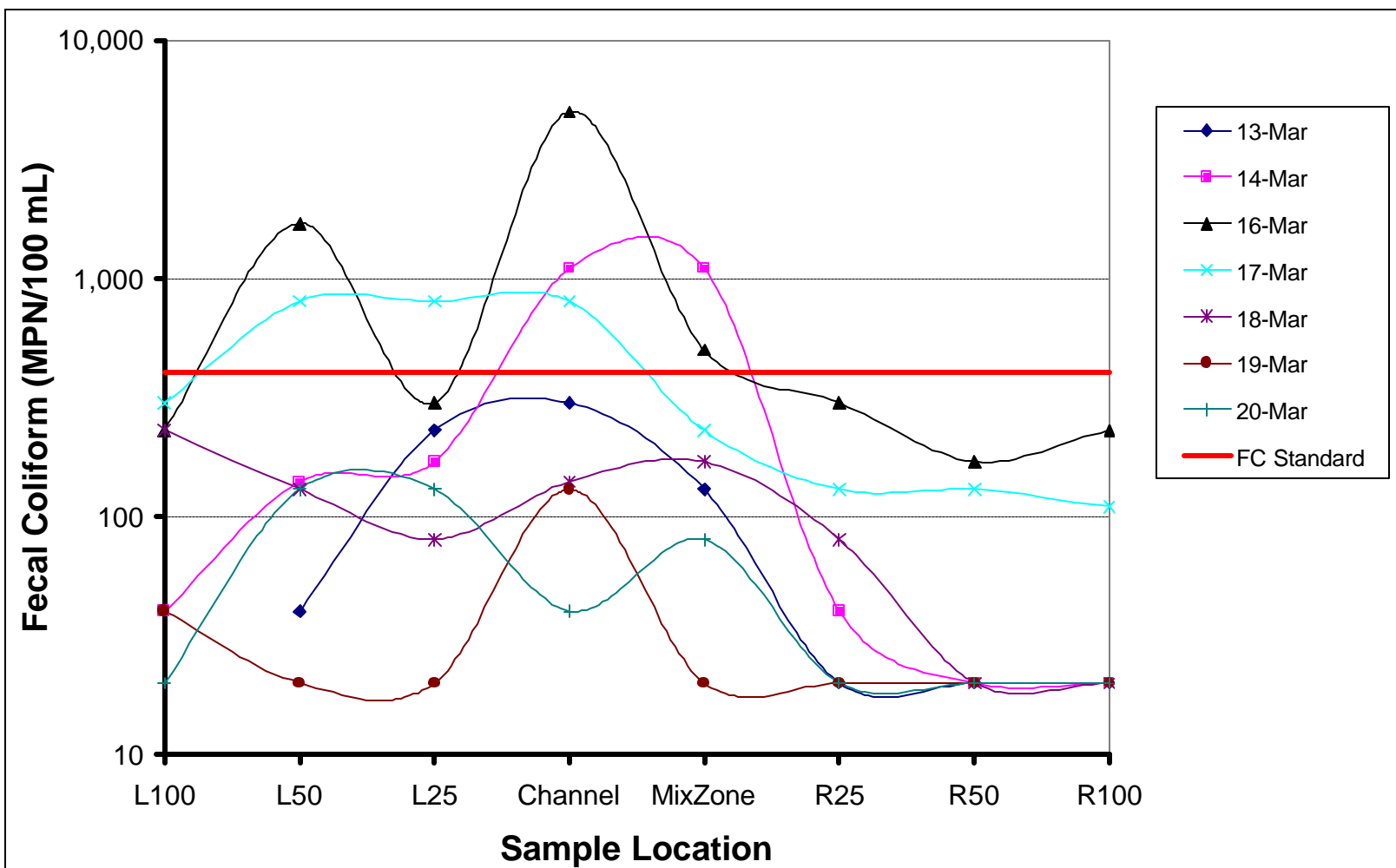


Figure 11B. Fecal Coliform at San Elijo State Beach

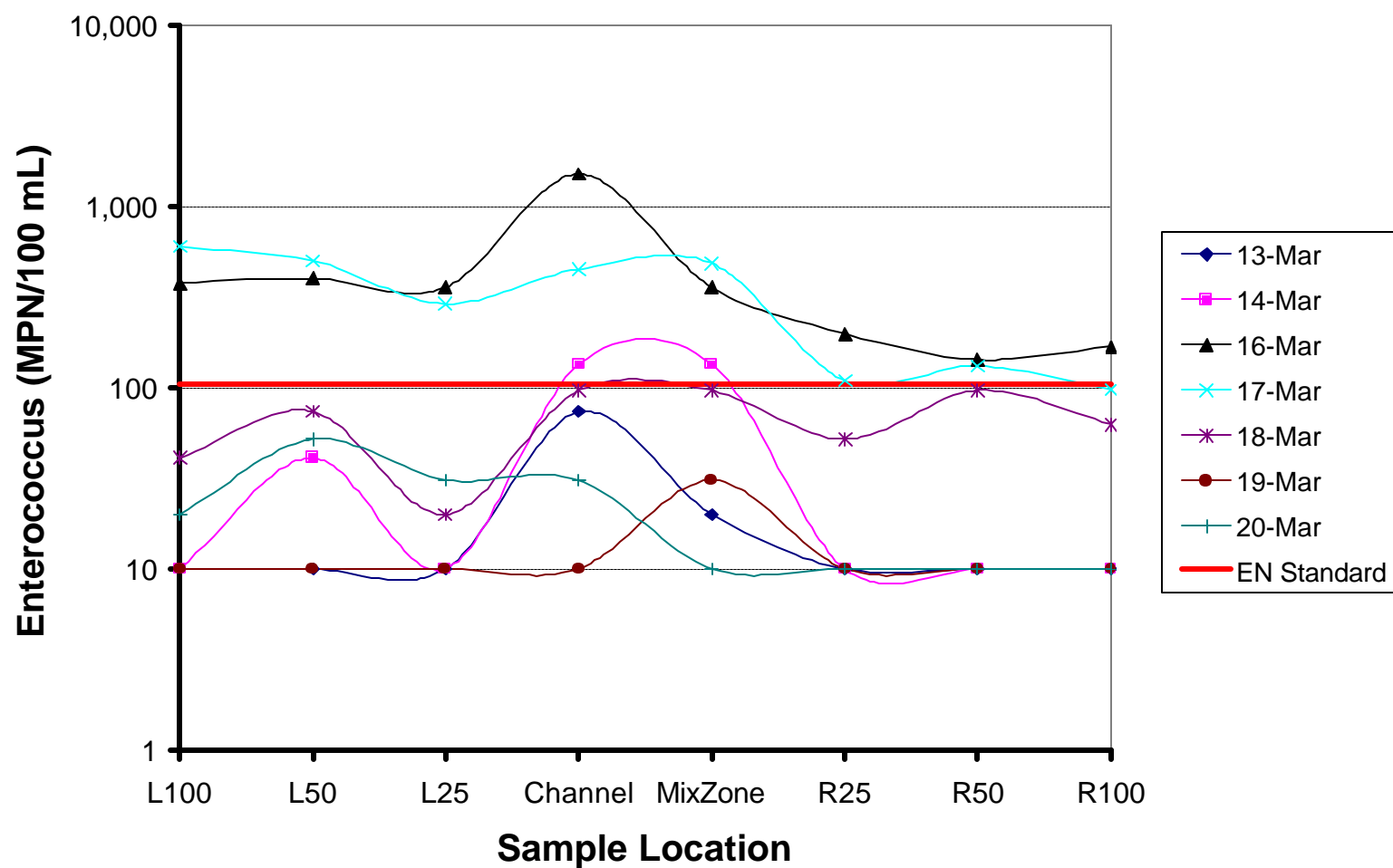
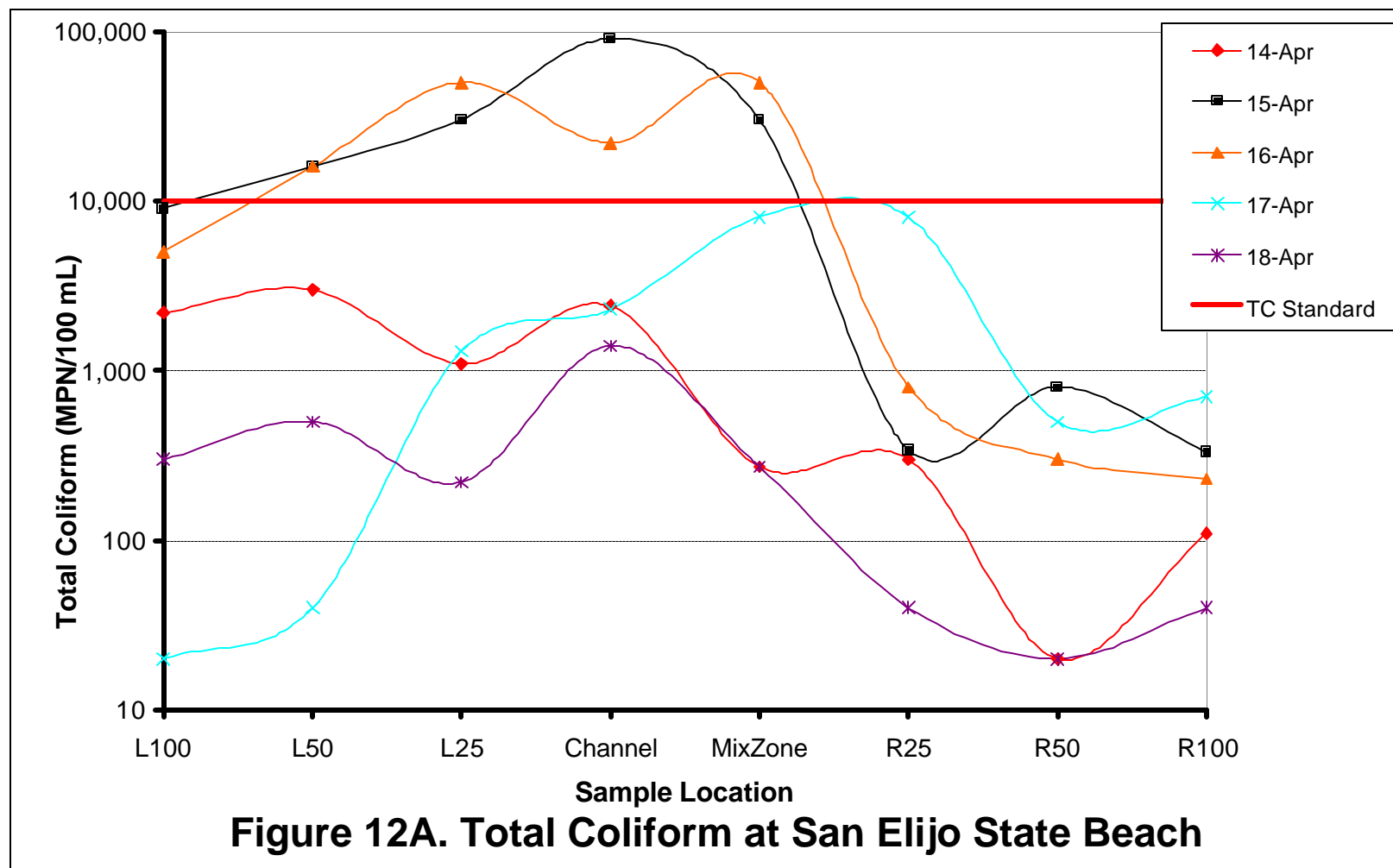


Figure 11C. Enterococcus at San Elijo State Beach



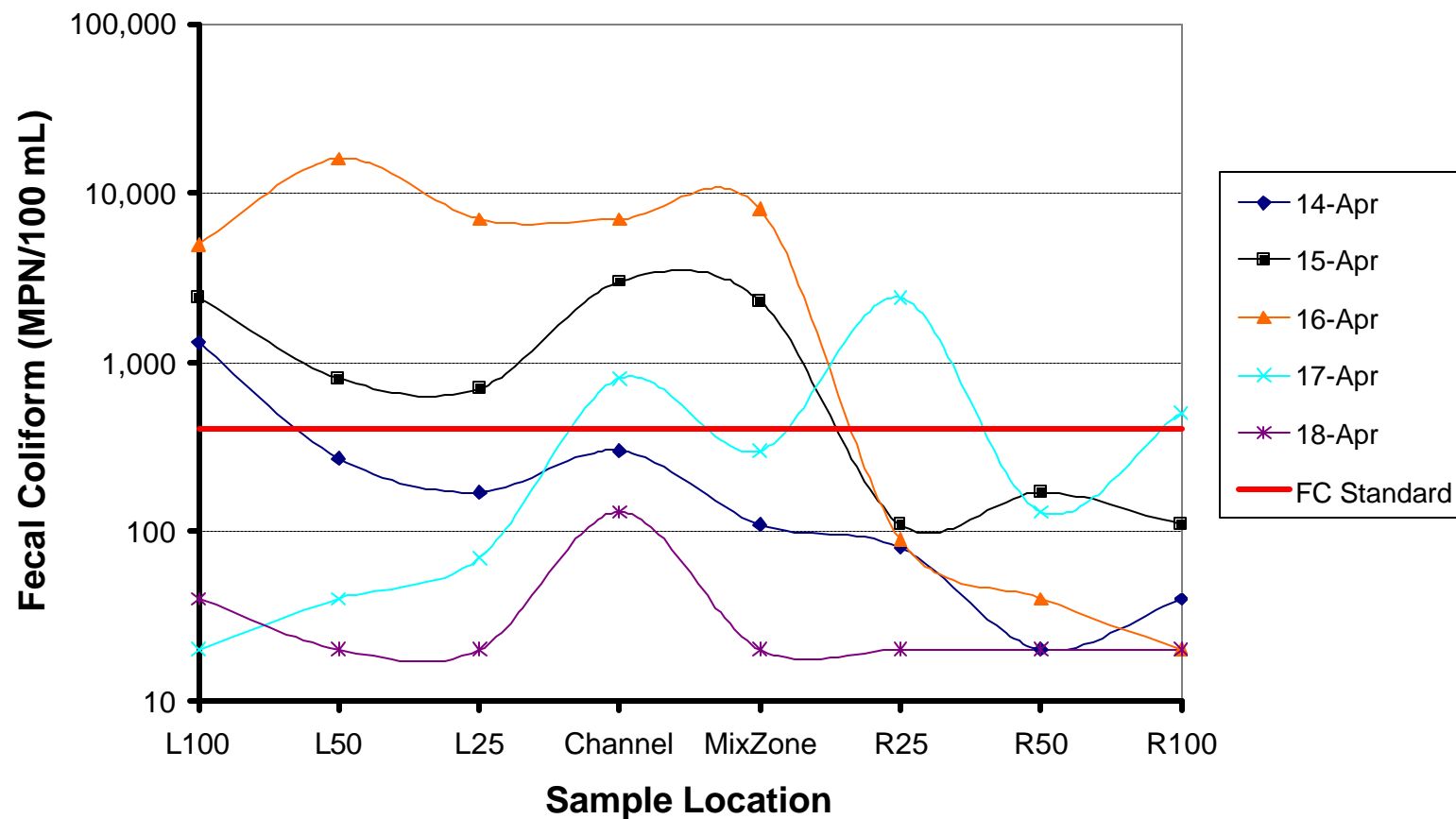


Figure 12B. Fecal Coliform at San Elijo State Beach

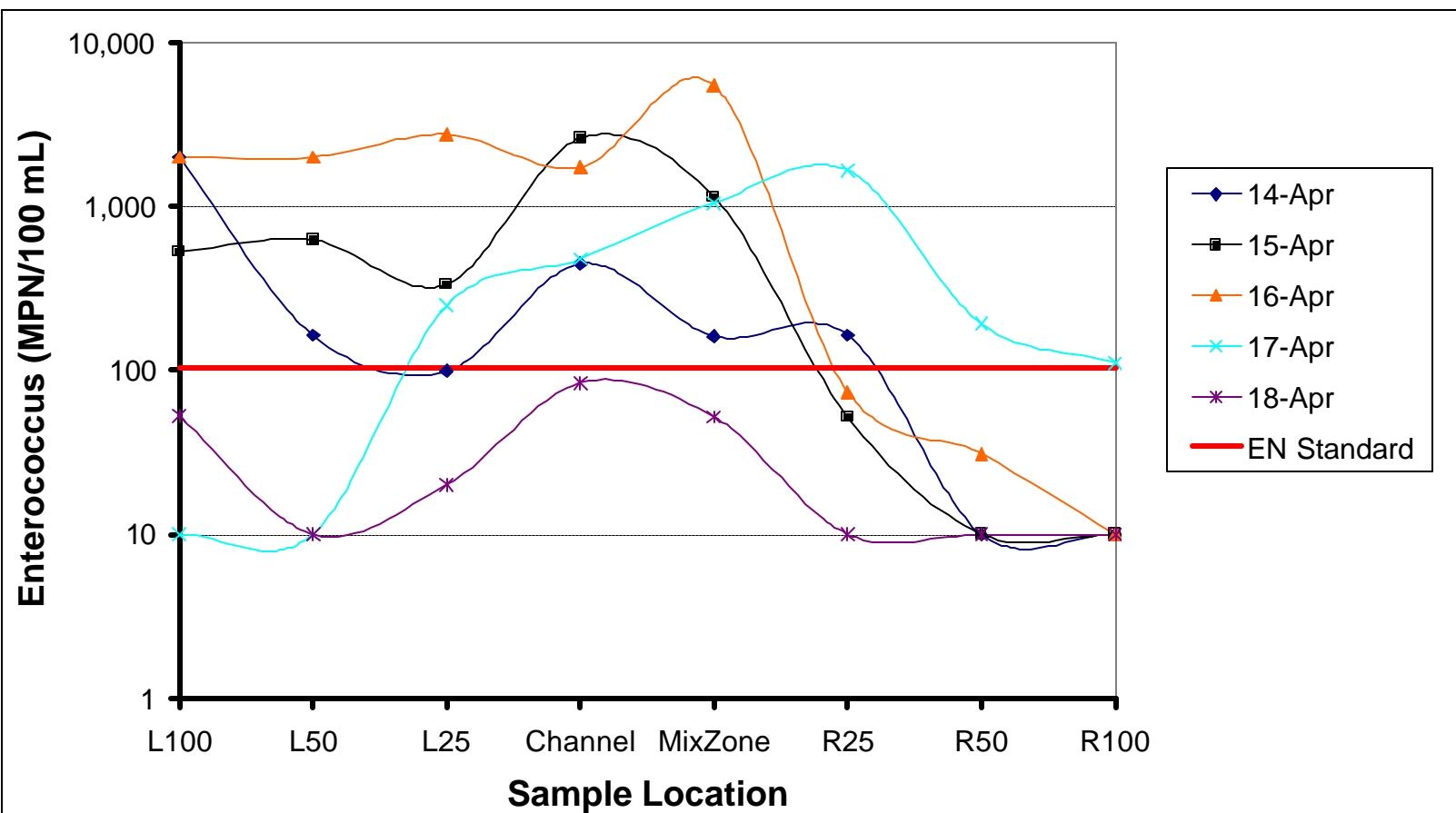


Figure 12C. Enterococcus at San Elijo State Beach

Data Tables

Table 2. Data from Torrey Pines State Beach at Los Penasquitos Lagoon

Sample Date & Time	*Direction from m.z., facing ocean	†Distance from m.z.	Total Coliform	Fecal Coliform	Enterococcus	Air Temp	PH	Conductivity	Turbidity	DO	Water Temp	Salinity
		(Yard)	(MPN/100 mL)			(°C)	(Unit)	mS/cm	(NTU)	(mg/L)	(°C)	(%)
3/13/03 10:35 AM	R	200	80	40	31	15.00	8.19	45.70	2.00	5.55	17.00	2.96
3/13/03 10:45 AM	R	100	130	110	10	15.00	8.23	47.80	1.67	5.39	16.53	3.10
3/13/03 10:55 AM	R	50	40	40	<10	15.30	8.27	49.27	1.67	5.72	16.43	3.21
3/13/03 11:10 AM	R	25	170	40	10	15.50	8.29	49.37	1.50	8.94	16.47	3.21
3/13/03 11:30 AM	M	0	500	80	10	14.50	8.22	45.97	3.00	5.48	17.00	2.97
3/13/03 11:31 AM	M	0	170	80	10	14.50	8.22	45.97	3.00	5.48	17.00	2.97
3/13/03 11:40 AM	L	25	40	20	<10	16.20	8.27	49.00	2.33	5.59	16.80	3.19
3/13/03 11:50 AM	L	50	20	20	<10	16.80	8.26	49.67	1.83	6.19	16.83	3.24
3/13/03 12:15 PM	M	-20	1700	170	31	15.00	8.14	32.00	5.33	5.23	18.73	2.00
3/13/03 12:16 PM	M	-20	700	170	31	15.00	8.14	32.00	5.33	5.23	18.73	2.00
3/14/03 10:25 AM	R	100	300	130	<10	16.70	8.18	45.47	1.50	5.53	16.43	2.92
3/14/03 10:35 AM	R	50	500	130	41	16.30	8.18	43.17	3.00	5.09	16.37	2.77
3/14/03 10:50 AM	R	25	500	230	52	15.90	8.22	44.47	2.17	5.03	16.43	2.86
3/14/03 11:00 AM	M	0	2200	500	85	16.00	8.14	37.70	6.00	4.52	16.93	2.39
3/14/03 11:30 AM	L	25	500	130	20	15.00	8.24	47.20	3.00	5.26	16.63	3.06
3/14/03 11:35 AM	L	50	300	80	52	15.40	8.23	45.77	3.33	5.83	17.13	2.96
3/14/03 11:45 AM	L	100	<20	<20	20	16.40	8.26	48.10	1.67	5.25	17.03	3.12
3/14/03 12:10 PM	M	-20	500	170	20	15.60	8.17	39.30	4.33	4.81	17.60	2.50
3/14/03 12:11 PM	M	-20	1700	300	20	15.60	8.17	39.30	4.33	4.81	17.60	2.50
3/16/03 12:35 PM	M	-20	160000	8000	12033	14.00	7.70	1.30	123.00	3.96	15.05	0.06
3/16/03 12:45 PM	M	0	90000	24000	14136	13.80	7.93	5.92	121.50	5.44	15.10	0.31
3/16/03 12:55 PM	R	25	24000	9000	9804	13.70	7.90	14.15	95.00	5.22	15.20	0.81
3/16/03 1:20 PM	R	50	9000	5000	3873	14.10	7.85	5.11	122.00	5.08	15.15	0.26
3/16/03 1:25 PM	R	100	5000	3000	3441	14.80	7.87	5.52	119.50	5.01	15.40	0.29
3/16/03 1:45 PM	L	25	50000	9000	10642	14.70	7.92	10.85	134.00	5.38	15.50	0.60
3/16/03 1:50 PM	L	50	>16000	5000	1553	14.40	7.87	3.23	155.00	5.06	15.70	0.16
3/16/03 2:10 PM	L	100	16000	2400	14136	13.70	7.99	8.93	130.50	5.50	16.10	0.49
3/17/03 1:00 PM	M	-20	30000	1100	3076	13.60	7.80	7.42	29.50	5.29	16.15	0.39
3/17/03 1:10 PM	M	0	17000	5000	2909	12.80	7.85	9.34	28.00	5.16	16.10	0.51
3/17/03 1:20 PM	R	25	17000	1300	3448	13.00	8.07	20.95	26.50	5.74	16.10	1.25
3/17/03 1:45 PM	R	50	5000	1300	2009	13.30	8.15	29.25	19.00	5.39	16.10	1.81
3/17/03 1:55 PM	R	100	3000	80	121	12.90	8.24	48.30	8.00	5.70	15.60	3.14
3/17/03 2:05 PM	L	25	30000	1700	2382	13.70	8.04	13.00	24.50	5.76	16.70	0.74
3/17/03 2:15 PM	L	50	3500	1400	3654	13.60	7.99	16.40	22.50	5.46	16.55	0.96
3/17/03 2:30 PM	L	100	9000	3000	820	13.90	8.00	16.80	23.00	5.30	16.60	0.98
3/18/03 1:15 PM	R	25	16000	300	109	16.10	8.13	36.85	23.00	5.19	17.35	2.33
3/18/03 1:25 PM	R	50	3000	170	195	14.20	8.16	37.05	23.00	5.32	16.85	2.34
3/18/03 1:30 PM	R	100	170	80	41	14.50	8.24	50.65	17.00	5.32	15.85	3.29
3/18/03 1:50 PM	L	25	3000	130	209	14.80	8.21	29.55	10.50	4.95	17.20	1.83
3/18/03 2:00 PM	L	50	1300	130	52	15.50	8.23	44.70	15.50	5.38	16.25	2.87

3/18/03 2:15 PM	L	100	500	230	228	14.20	8.20	31.20	11.50	5.50	17.55	1.94
3/18/03 2:30 PM	M	0	5000	800	193	14.50	8.10	23.75	9.00	5.62	17.25	1.44
3/18/03 2:45 PM	M	-20	9000	800	203	14.50	8.06	22.05	10.00	5.70	17.70	1.33
3/19/03 1:45 PM	R	25	5000	170	41	15.70	8.13	34.60	10.00	5.94	18.00	2.18
3/19/03 2:00 PM	R	50	260	300	10	15.40	8.17	42.70	11.00	6.24	17.50	2.73
3/19/03 2:05 PM	R	100	1400	170	10	16.50	8.18	40.50	10.00	6.29	17.50	2.59
3/19/03 2:20 PM	M	-20	500	80	41	17.20	8.08	28.70	17.00	5.97	18.50	1.77
3/19/03 2:21 PM	M	-20	1700	110	63	17.20	8.08	28.70	17.00	5.97	18.50	1.77
3/19/03 2:40 PM	M	0	800	230	31	18.00	8.09	27.40	7.00	6.04	18.60	1.68
3/19/03 2:50 PM	L	25	80	20	20	17.30	8.20	48.60	9.00	6.45	16.50	3.15
3/19/03 3:00 PM	L	50	800	130	20	17.10	8.17	37.60	10.00	5.97	17.90	2.39
3/19/03 3:10 PM	L	100	500	110	31	15.70	8.20	47.00	8.00	6.20	16.70	3.04
3/19/03 3:11 PM	L	100	<20	<20	<10	15.70	8.20	47.00	8.00	6.20	16.70	3.04
3/20/03 2:13 PM	R	25	80	<20	10	16.10	8.25	49.20	7.00	6.12	16.90	3.19
3/20/03 2:20 PM	R	50	230	<20	10	16.70	8.26	49.00	6.00	6.01	16.90	3.19
3/20/03 2:28 PM	R	100	20	<20	<10	17.20	8.26	50.00	10.00	6.24	16.80	3.25
3/20/03 2:37 PM	L	25	70	40	<10	16.00	8.26	49.80	7.00	6.17	16.50	3.22
3/20/03 2:45 PM	L	50	340	70	145	16.50	8.21	42.10	7.00	5.97	17.40	2.70
3/20/03 2:50 PM	L	100	40	<20	<10	16.40	8.25	49.90	5.00	6.44	16.30	3.24
3/20/03 3:00 PM	M	0	700	300	98	16.50	8.14	27.30	6.00	6.19	18.60	1.67
3/20/03 3:01 PM	M	0	1400	230	74	16.50	8.14	27.30	6.00	6.19	18.60	1.67
3/20/03 3:06 PM	M	-20	1700	130	74	16.40	8.11	25.90	5.00	6.18	18.80	1.58
3/20/03 3:07 PM	M	-20	600	230	109	16.40	8.11	25.90	5.00	6.18	18.80	1.58
4/14/03 1:15 PM	M	0	<20	<20	<10	ND	ND	ND	ND	ND	ND	ND
4/14/03 1:25 PM	R	50	20	<20	10	ND	ND	ND	ND	ND	ND	ND
4/14/03 1:30 PM	L	50	<20	<20	<10	ND	ND	ND	ND	ND	ND	ND
4/14/03 1:40 PM	M	-20	9000	1300	712	ND	ND	ND	ND	ND	ND	ND
4/15/03 1:45 PM	M	0	90000	5000	4352	16.80	8.11	1.85	75.00	4.90	16.90	0.08
4/15/03 1:46 PM	M	0	>160000	11000	7270	16.80	8.11	1.85	75.00	4.90	16.90	0.08
4/15/03 1:55 PM	R	25	90000	8000	7701	15.50	7.99	4.48	83.00	5.13	17.50	0.23
4/15/03 2:00 PM	R	50	3000	2400	>2005	14.80	8.23	30.10	27.00	5.27	17.10	1.86
4/15/03 2:08 PM	R	100	2400	1300	>2005	16.10	8.35	26.40	49.00	5.65	16.90	1.61
4/15/03 2:20 PM	L	25	160000	24000	8664	14.90	8.36	7.15	42.00	5.21	17.50	0.38
4/15/03 2:30 PM	L	50	3500	1300	>2005	14.80	8.14	80.40	46.00	5.86	17.70	0.43
4/15/03 2:40 PM	L	100	9000	3000	>2005	13.80	8.14	9.38	62.00	5.66	17.50	0.51
4/15/03 2:55 PM	M	-20	90000	17000	8664	15.40	8.31	1.65	51.00	5.07	17.80	0.07
4/15/03 2:56 PM	M	-20	90000	8000	9804	15.40	8.31	1.65	51.00	5.07	17.80	0.07
4/16/03 1:55 PM	M	-20	13000	1300	697	16.50	7.90	10.50	12.00	5.41	18.20	0.59
4/16/03 2:00 PM	R	25	5000	500	669	16.30	7.82	15.30	29.00	5.52	17.90	0.89
4/16/03 2:05 PM	R	50	1300	500	504	15.10	7.95	27.50	25.00	5.55	17.30	1.69
4/16/03 2:10 PM	R	100	1300	500	324	15.40	7.96	21.70	12.00	5.02	17.80	1.30
4/16/03 2:15 PM	M	0	5000	500	556	15.50	7.97	23.70	23.00	5.27	17.70	1.43
4/16/03 2:20 PM	L	25	7000	300	276	16.20	8.03	32.30	21.00	5.31	17.20	2.01
4/16/03 2:30 PM	L	50	2400	1300	64	16.30	8.08	39.40	25.00	5.15	16.90	2.51
4/16/03 2:35 PM	L	100	5000	1100	238	14.40	8.05	31.00	27.00	5.83	17.40	1.92
4/17/03 1:55 PM	M	-20	2300	170	148	16.10	7.91	23.20	30.00	5.13	16.50	1.39
4/17/03 2:05 PM	M	0	1300	170	146	15.10	7.87	25.50	8.00	4.81	16.40	1.56
4/17/03 2:10 PM	R	25	3500	130	132	14.80	7.89	27.50	7.00	5.20	16.60	1.69
4/17/03 2:15 PM	R	50	1300	230	192	14.90	7.89	25.20	13.00	5.25	17.20	1.53
4/17/03 2:25 PM	R	100	400	<20	64	16.00	7.97	32.40	24.00	4.94	17.20	2.02

4/17/03 2:40 PM	L	25	5000	40	52	14.10	8.03	40.70	18.00	4.98	16.30	2.59
4/17/03 2:45 PM	L	50	800	230	53	15.50	8.05	42.10	6.00	5.25	16.40	2.69
4/17/03 3:00 PM	L	100	230	40	20	15.50	8.08	46.40	17.00	4.81	16.90	3.00
4/17/03 3:01 PM	L	100	<20	<20	<10	15.50	8.08	46.40	17.00	4.81	16.90	3.00
4/18/03 2:00 PM	R	25	80	<20	<10	16.30	8.10	48.80	3.00	4.63	16.60	3.17
4/18/03 2:10 PM	R	50	90	20	10	16.40	8.12	48.70	17.00	5.67	16.50	3.18
4/18/03 2:15 PM	R	100	40	20	<10	15.10	8.12	49.20	7.00	5.35	16.50	3.20
4/18/03 2:25 PM	L	25	3000	80	20	15.90	8.08	42.00	5.00	5.17	17.20	2.69
4/18/03 2:35 PM	L	50	270	<20	<10	15.00	8.11	46.10	15.00	4.88	16.60	2.99
4/18/03 2:40 PM	L	100	130	80	20	15.50	8.10	45.70	7.00	4.54	16.80	2.95
4/18/03 2:50 PM	M	0	5000	40	52	15.10	8.04	33.40	13.00	5.22	18.20	2.09
4/18/03 2:55 PM	M	-20	2200	230	74	16.30	8.00	9.90	15.00	7.13	19.50	0.55
4/18/03 2:56 PM	M	-20	2800	130	31	16.30	8.00	9.90	15.00	7.13	19.50	0.55
7/17/03 7:45 AM	M	-20	800	130	10	ND	ND	ND	ND	ND	21.8	2.95
7/17/03 7:46 AM	M	-20	1700	120	41	ND	ND	ND	ND	ND	ND	ND
7/17/03 7:48 AM	M	0	900	170	41	ND	ND	ND	ND	ND	21.1	3.45
7/17/03 7:50 AM	R	25	140	<20	96	ND	ND	ND	ND	ND	ND	ND
7/17/03 7:52 AM	R	50	40	20	41	ND	ND	ND	ND	ND	21.2	3.36
7/17/03 8:00 AM	R	100	300	80	10	ND	ND	ND	ND	ND	ND	ND
7/17/03 8:03 AM	R	300	20	20	10	ND	ND	ND	ND	ND	ND	ND
7/17/03 8:12 AM	L	25	20	<20	<10	ND	ND	ND	ND	ND	ND	ND
7/17/03 8:14 AM	L	50	<20	<20	10	ND	ND	ND	ND	ND	ND	ND

* L= left, R = right, M = mixing zone.

† 0 = at the mixing point, -20 = at the mouth of lagoon outlet.

ND = Not determined.

Table 3. Data from Cardiff State Beach at San Elijo Lagoon

Sample Date & Time	*Direction from m.z., facing ocean	†Distance from m.z.	Total Coliform	Fecal Coliform	Enterococcus	Air Temp.	PH	Conductivity	Turbidity	DO	Water Temp.	Salinity
		(Yard)	(MPN/100 mL)			(°C)	(Unit)	mS/cm	(NTU)	(mg/L)	(°C)	(%)
3/13/03 1:10 PM	R	200	<20	<20	<10	17.10	8.31	50.13	1.50	5.82	17.87	3.27
3/13/03 1:20 PM	R	100	20	20	10	16.70	8.36	50.33	1.00	5.34	17.73	3.28
3/13/03 1:30 PM	R	50	<20	<20	10	16.30	8.36	50.10	1.00	5.94	17.33	3.26
3/13/03 1:45 PM	R	25	<20	<20	<10	19.00	8.38	50.10	3.00	6.50	17.00	3.26
3/13/03 2:00 PM	M	0	300	130	20	18.10	8.22	35.77	9.00	5.79	18.40	2.25
3/13/03 2:10 PM	L	25	230	230	10	17.20	8.09	19.70	18.00	5.15	19.00	1.17
3/13/03 2:20 PM	L	50	300	40	<10	17.20	8.27	42.10	5.00	5.40	17.80	2.70
3/13/03 2:35 PM	M	-20	1400	300	74	17.00	7.97	10.20	23.00	5.00	19.20	0.56
3/14/03 1:00 PM	R	100	<20	<20	<10	16.50	8.36	50.43	0.83	5.35	17.20	3.29
3/14/03 1:15 PM	R	50	<20	<20	<10	17.20	8.38	50.27	1.00	5.36	17.53	3.29
3/14/03 1:20 PM	R	25	80	40	<10	16.30	8.35	50.20	0.00	5.96	16.50	3.26
3/14/03 1:35 PM	M	0	1700	1100	135	15.90	8.06	21.17	17.17	4.58	17.90	1.27
3/14/03 1:45 PM	L	25	500	170	<10	15.80	8.28	40.63	6.00	5.64	17.63	2.59
3/14/03 2:00 PM	L	50	800	140	41	16.20	8.31	43.60	3.50	6.02	17.30	2.80
3/14/03 2:10 PM	L	100	300	40	10	15.90	8.30	47.53	2.33	6.00	17.00	3.08
3/14/03 2:25 PM	M	-20	1700	1100	135	16.20	7.98	15.90	21.33	4.19	18.20	0.92
3/14/03 2:26 PM	M	-20	1700	300	63	16.20	7.98	15.90	21.33	4.19	18.20	0.92
3/16/03 10:30 AM	M	0	800	500	359	13.60	8.13	49.70	15.50	5.38	15.30	3.23
3/16/03 10:40 AM	L	25	1700	300	359	13.80	8.18	49.55	11.50	5.55	15.25	3.23
3/16/03 10:50 AM	L	100	2200	230	379	13.80	8.18	49.45	17.00	5.43	15.30	3.21
3/16/03 10:55 AM	L	50	1700	1700	404	13.60	8.18	49.35	13.00	5.53	15.25	3.21
3/16/03 11:05 AM	M	-20	13000	13000	472	13.90	8.14	47.90	13.50	5.31	15.25	3.11
3/16/03 11:20 AM	R	25	2400	300	199	13.60	8.21	49.55	9.00	5.31	15.40	3.22
3/16/03 11:30 AM	R	50	700	170	143	13.50	8.24	49.70	9.50	5.11	15.50	3.29
3/16/03 11:40 AM	R	100	900	230	169	13.80	8.27	50.15	9.00	5.28	15.55	3.26
3/16/03 12:00 PM	M	-20	90000	5000	1515	14.00	8.12	45.65	16.00	4.93	15.35	2.95
3/17/03 10:30 AM	M	-20	5000	800	452	14.00	8.20	47.40	15.50	5.21	15.75	3.07
3/17/03 10:40 AM	M	0	2800	230	487	13.70	8.19	48.20	30.50	5.46	15.80	3.13
3/17/03 10:50 AM	L	25	3000	800	292	12.50	8.20	47.95	24.50	10.44	15.80	3.11
3/17/03 11:00 AM	L	50	5000	800	504	13.10	8.21	47.30	14.00	5.84	15.80	3.07
3/17/03 11:10 AM	L	100	5900	300	605	13.60	8.19	46.60	26.00	5.38	15.90	3.02
3/17/03 11:20 AM	R	25	2400	130	110	13.10	8.24	49.30	31.50	5.61	16.20	3.16
3/17/03 11:30 AM	R	50	3000	130	132	13.60	8.25	49.40	12.50	5.53	16.10	3.22
3/17/03 11:45 AM	R	100	5000	110	98	13.80	8.24	49.40	22.00	5.08	16.25	3.22
3/18/03 10:40 AM	M	0	340	170	97	16.00	8.18	49.90	44.00	5.72	15.75	3.25
3/18/03 10:50 AM	L	50	330	130	74	14.60	8.23	50.15	24.00	5.44	15.50	3.26
3/18/03 11:20 AM	L	25	500	80	20	14.00	8.23	50.30	24.50	5.30	15.90	3.27
3/18/03 11:30 AM	L	100	500	230	41	14.10	8.24	50.30	20.50	4.46	15.45	3.26
3/18/03 11:45 AM	R	25	1400	80	52	14.60	8.25	50.75	32.50	5.00	15.35	3.30

3/18/03 11:55 AM	R	50	230	20	97	14.00	8.26	50.75	18.50	5.54	15.20	3.29
3/18/03 12:00 PM	R	100	500	<20	63	14.20	8.25	50.75	24.00	5.15	15.30	3.30
3/18/03 12:15 PM	M	-20	1100	140	97	14.40	8.23	47.35	13.50	19.98	17.10	3.07
3/19/03 12:00 PM	M	0	70	20	31	15.70	8.08	49.80	17.00	6.22	16.80	3.23
3/19/03 12:10 PM	L	25	130	20	<10	15.10	8.17	50.00	16.00	6.01	16.50	3.26
3/19/03 12:20 PM	L	50	800	<20	10	14.90	8.19	50.10	28.00	6.14	16.30	3.25
3/19/03 12:25 PM	L	100	220	40	10	15.30	8.18	50.00	15.00	6.05	16.40	3.25
3/19/03 12:35 PM	R	25	130	20	10	15.10	8.21	50.80	13.00	6.44	16.20	3.29
3/19/03 12:45 PM	R	50	130	<20	<10	15.50	8.22	50.60	14.00	6.49	15.80	3.30
3/19/03 12:50 PM	R	100	130	20	<10	16.00	8.21	50.80	10.00	6.28	15.90	3.29
3/19/03 1:10 PM	M	-20	120	<20	31	15.90	8.24	46.90	10.00	6.51	18.60	3.03
3/19/03 1:11 PM	M	-20	270	130	<10	15.90	8.24	46.90	10.00	6.51	18.60	3.03
3/20/03 12:35 PM	R	25	40	<20	<10	16.10	8.21	49.80	23.00	6.50	16.50	3.24
3/20/03 12:36 PM	R	25	<20	<20	<10	16.10	8.21	49.80	23.00	6.50	16.50	3.24
3/20/03 12:50 PM	R	50	20	<20	<10	15.80	8.25	50.40	8.00	6.51	16.10	3.27
3/20/03 12:58 PM	R	100	20	<20	<10	16.30	8.24	50.60	10.00	6.32	16.30	3.29
3/20/03 1:09 PM	M	0	5000	1700	<10	16.80	8.14	38.00	12.00	5.87	17.90	2.41
3/20/03 1:10 PM	M	0	600	80	10	16.80	8.14	38.00	12.00	5.87	17.90	2.41
3/20/03 1:21 PM	M	-20	700	170	31	16.10	8.13	35.90	12.00	6.03	18.20	2.26
3/20/03 1:22 PM	M	-20	1400	40	31	16.10	8.13	35.90	12.00	6.03	18.20	2.26
3/20/03 1:29 PM	L	25	340	130	31	16.60	8.16	42.20	13.00	5.83	17.60	2.71
3/20/03 1:33 PM	L	50	700	130	52	18.00	8.15	40.60	17.00	5.81	18.20	2.59
3/20/03 1:39 PM	L	100	1300	20	20	16.40	8.15	38.60	15.00	5.87	18.20	2.46
4/14/03 11:00 AM	M	0	270	110	161	17.00	8.18	49.90	9.00	6.43	17.00	3.26
4/14/03 11:10 AM	L	25	1100	170	99	16.50	8.29	50.50	4.00	6.04	16.70	3.30
4/14/03 11:20 AM	L	50	3000	270	164	15.70	8.30	50.60	5.00	5.73	16.50	3.30
4/14/03 11:25 AM	L	100	2200	1300	>2005	15.90	8.30	50.70	5.00	5.81	16.50	3.30
4/14/03 11:30 AM	M	-20	2400	300	450	16.00	8.26	49.40	2.00	5.32	16.70	3.21
4/14/03 11:31 AM	M	-20	1300	500	479	16.00	8.26	49.40	2.00	5.32	16.70	3.21
4/14/03 11:50 AM	R	25	300	80	164	16.00	8.24	47.80	7.00	5.93	16.80	3.11
4/14/03 11:55 AM	R	50	20	20	10	15.60	8.33	51.10	2.00	5.93	16.40	3.33
4/14/03 12:10 PM	R	100	110	40	10	15.80	8.34	51.10	4.00	5.27	16.50	3.33
4/15/03 11:50 AM	M	0	30000	2300	1145	14.80	8.23	38.50	32.00	4.84	16.30	2.44
4/15/03 12:00 PM	L	25	30000	700	335	14.50	8.37	44.20	10.00	4.47	16.50	2.84
4/15/03 12:10 PM	L	50	>16000	800	624	16.50	8.38	42.10	14.00	4.86	16.40	2.69
4/15/03 12:20 PM	L	100	9000	2400	531	16.10	8.38	42.30	27.00	4.70	116.30	2.71
4/15/03 12:30 PM	M	-20	90000	3000	2613	17.30	8.27	28.30	40.00	4.75	16.30	1.75
4/15/03 12:45 PM	R	25	340	110	52	16.90	8.43	47.20	24.00	4.70	17.20	3.06
4/15/03 1:00 PM	R	50	800	170	<10	16.20	8.49	50.00	12.00	4.57	17.00	3.27
4/15/03 1:05 PM	R	100	330	110	10	16.50	8.49	50.30	6.00	5.08	17.00	3.27
4/16/03 12:00 PM	M	0	50000	8000	5475	16.80	7.81	28.00	23.00	5.31	16.50	1.72
4/16/03 12:10 PM	L	25	50000	7000	2755	15.60	7.93	32.50	40.00	5.01	16.20	2.02
4/16/03 12:17 PM	L	50	>16000	>16000	>2005	15.20	7.88	27.60	45.00	5.25	16.20	1.69
4/16/03 12:25 PM	L	100	5000	5000	>2005	15.50	7.87	26.40	23.00	5.25	16.10	1.62
4/16/03 12:50 PM	R	25	800	90	74	16.10	8.15	49.40	24.00	4.76	16.70	3.21
4/16/03 12:55 PM	R	50	300	40	31	15.50	8.16	49.70	4.00	5.15	16.20	3.23
4/16/03 1:00 PM	R	100	230	20	<10	15.50	8.15	49.90	24.00	4.79	16.40	3.25
4/16/03 1:05 PM	M	-20	22000	7000	1727	16.50	7.93	6.55	55.00	4.31	17.50	0.34
4/17/03 12:15 PM	M	0	8000	300	1050	15.70	7.65	39.60	14.00	5.08	15.10	2.50
4/17/03 12:20 PM	L	25	1300	70	249	15.50	8.03	49.80	8.00	5.11	14.70	3.23

4/17/03 12:25 PM	L	50	40	40	10	15.40	8.08	50.50	8.00	4.83	14.80	3.28
4/17/03 12:35 PM	L	100	20	20	<10	16.80	8.09	50.50	11.00	5.00	15.00	3.28
4/17/03 12:45 PM	M	-20	2300	800	480	15.70	7.94	30.00	27.00	4.43	15.10	1.90
4/17/03 1:00 PM	R	25	8000	2400	1658	18.20	7.95	38.70	57.00	5.12	15.40	2.45
4/17/03 1:05 PM	R	50	500	130	192	14.50	8.04	49.70	9.00	4.90	15.60	3.22
4/17/03 1:15 PM	R	100	700	500	111	17.80	8.09	49.80	27.00	5.23	15.50	3.23
4/18/03 12:35 PM	M	0	270	20	52	16.00	8.03	43.70	9.00	4.53	17.70	2.82
4/18/03 12:45 PM	L	25	220	20	20	14.50	8.11	48.00	14.00	4.56	16.90	3.11
4/18/03 12:50 PM	L	50	500	<20	<10	15.10	8.11	47.60	24.00	4.57	16.70	3.08
4/18/03 12:55 PM	L	100	300	40	53	14.30	8.08	45.90	25.00	4.60	16.80	2.97
4/18/03 1:05 PM	R	25	40	<20	<10	16.90	8.14	50.00	14.00	4.78	16.50	3.28
4/18/03 1:15 PM	R	50	<20	<20	<10	15.90	8.15	50.20	5.00	5.14	16.50	3.27
4/18/03 1:25 PM	R	100	40	20	<10	16.60	8.16	50.10	4.00	4.81	16.30	3.27
4/18/03 1:30 PM	M	-20	1400	130	84	16.10	7.86	27.80	35.00	4.38	17.80	1.71
7/17/03 8:40 AM	M	-20	140	140	<10	ND	ND	ND	ND	ND	21.80	3.22
7/17/03 8:46 AM	M	-20	130	80	10	ND	ND	ND	ND	ND	ND	ND
7/17/03 8:50 AM	M	0	20	<20	20	ND	ND	ND	ND	ND	22.00	3.41
7/17/03 9:00 AM	L	25	230	130	41	ND	ND	ND	ND	ND	ND	ND
7/17/03 9:05 AM	L	50	230	170	20	ND	ND	ND	ND	ND	ND	ND
7/17/03 9:10 AM	R	25	300	110	110	ND	ND	ND	ND	ND	ND	ND
7/17/03 9:13 AM	R	50	<20	<20	<10	ND	ND	ND	ND	ND	22.50	3.41
7/17/03 9:20 AM	R	100	40	20	<10	ND	ND	ND	ND	ND	ND	ND
7/17/03 9:25 AM	R	300	20	<20	<10	ND	ND	ND	ND	ND	ND	ND

* L= left, R = right, M = mixing zone.

† 0 = at the mixing point, -20 = at the mouth of lagoon outlet.

ND = Not determined.